Report MDC-J-3871

NINTH ANNUAL SUMMARY REPORT

Flight Service Program for Advanced Composite Rudders on Transport Aircraft

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LONG BEACH, CALIFORNIA 90846

CONTRACT NAS1-12954
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National Aeronautics and
Space Administration

Langley Research Center
Hampton, Virginia 23665

SUMMARY

Flight service experience and in-service inspection results are reported for DC-10 carbon-epoxy rudders during their use by commercial airlines for 9 years. Twenty carbon-epoxy rudders were produced, and 15 have flown in aircraft operated by commercial airlines. The rudders have collectively accumulated 281,907 flight-hours in 108 months of service, with an average utilization of 9.5 hours per day. The high-time rudder has accumulated 32,133 hours in 95 months of service, for an average utilization of 11.4 hours per day. In-service inspections indicate that the rudders are acceptable for continued service.

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PREFACE

This report was prepared by Douglas Aircraft Company, of McDonnell Douglas Corporation, in Long Beach, California, under Contract NAS1-12954. It is the ninth annual summary report covering airline service experience between July 1, 1984 and June 30, 1985. The program is sponsored by the National Aeronautics and Space Administration (NASA), Langley Research Center. Marvin B. Dow is the Technical Representative of the Contracting Officer for NASA.

The following personnel were the principal contributors to the program during the reporting period:

Bruce R. Fox	Project Manager
H. Benson Dexter	NASA Environmental Tests
Mark E. Curley	Product Support
Rick Moore	Structural Repair

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SECTION 1

INTRODUCTION

Douglas Aircraft Company produced 20 advanced composite rudders for the DC-10 commercial transport aircraft under Contracts NAS1-12954 and NAS1-14724. The overall objectives of these contracts were (1) the development of technology to design and fabricate composite structural components for transport aircraft, (2) the acquisition of manufacturing cost data, (3) the development of confidence and experience in the use of composite materials in commercial aircraft, (4) the acquisition of maintenance experience and cost data during airline flight service, (5) the acquisition of data for correlating flight service behavior with ground-based tests, and (6) broadening the base of experience and confidence in composite usage. An additional objective of Contract NAS1-14724 was to reduce manufacturing costs through development of production tools and methods for the thermal expansion molding (trapped rubber) process.

Under Contract NAS1-12954, 10 rudders were designed and developed using Thornel 300/Narmco 5208 carbon-epoxy material in a unidirectional 3-inch tape form. The design, development, and testing of these rudders were reported in Reference 1. FAA certification was received in May 1976, and commercial flight service was initiated in June 1976. Under Contract NAS1-14724, an additional 10 rudders were designed and developed using Thornel 300/Narmco 5208 carbon-epoxy material in uniwoven and biwoven cloth forms. The design, development, and testing of these rudders was reported in Reference 2. FAA certification was received on May 3, 1979, and commercial flight service was initiated in February 1980.

Fifteen of the 20 advanced composite rudders have flown in commercial service. Two of these rudders are currently out of service. Rudder Serial No. 4, which had been in service 68 months and had accumulated 22,265 hours, was removed from flight service and ground tested at Douglas. The test is described in Reference 3. The test demonstrated that the rudder strength and stiffness characteristics were unchanged during its extended period of flight service. The other out-of-service rudder was removed after being damaged by lightning. The rudder is currently at Douglas for repair and evaluation, as described in Section 3.

The effects of outdoor environmental exposure on Thornel 300/Narmco 5208 laminate properties were investigated using ground-based exposure specimens from San Francisco International Airport and the NASA-Langley Research Center in Hampton, Virginia. The exposure periods began in October and November 1974, respectively. Laminate tensile strengths and elastic moduli have been determined by test after outdoor exposure for up to 10 years. Test results are summarized in Section 4. No significant trends on laminate strength or stiffness loss were indicated by these tests.

A flight evaluation program to determine the moisture absorption of carbon-epoxy laminates in the real-time flight environment ended in June 1980 after the laminates were exposed to this environment for 2 years. The moisture absorption data were obtained from flat rectangular specimens of three different carbon-epoxy laminates (Thornel 300/Narmco 5208, Thornel 300/Narmco 5209, and Hercules Type AS/3501-6) and two different thicknesses (8 and 16 plies). The results of this evaluation are in Reference 4. Average weight gains ranged from 0.29 and 0.81 percent, depending on material system, thickness, and aircraft installation location.

SECTION 2

RUDDER FLIGHT SERVICE

Fifteen composite rudders have been used in the flight service program. The remaining five rudders will be installed on commercial aircraft on a rotating basis as the metal forward rudders are modified, in turn, to accommodate thermal expansion. Two rudders have been removed from service. One rudder was taken out of service permanently after 68 months in order to conduct a static strength test. The other rudder was removed after being damaged by lightning. The rudder was sent to Douglas for evaluation and repair, as described in Section 4.

Two rudders were installed during this reporting period. On May 24, 1985, an ex-Air New Zealand rudder, Serial No. 5, which was removed in September 1982 when the original aircraft was sold, was returned to service aboard Finnair fuselage No. 201. On March 20, 1985, a new rudder was installed aboard Western fuselage No. 322.

The composite rudders have collectively accumulated 281,907 hours of flight service through June 1985. The high-time rudder has accumulated 32,133 hours in 7.9 years of service. The lead rudder has accumulated 30,574 hours in 9.1 years of service. The rudder flight service status through June 1985 is summarized in Tables 1 through 9.

So far, the service experience has been good, with no problems being reported for most of the rudders. However, there have been four incidents which required rudder repairs. Two lightning strike incidents resulted in minor surface damage, as reported in Reference 4. The damage was easily repaired on the aircraft by the operating airline. A composite rudder suffered a disbonded rib, which was believed to have been caused by ground handling, and had to be removed from the aircraft for repair. The damage and repair are described in detail in Reference 5. Another rudder was significantly damaged from a lightning strike and was removed from the aircraft for repair, as described in Section 4.

A composite rudder was routinely inspected on one occasion during the past year. Results of this latest and all earlier inspections are summarized in Table 10. All composite rudders have been judged acceptable for continued service as a result of these inspections.

TABLE 1
FLIGHT-TIME ACCUMULATIONS FOR DC-10 GRAPHITE COMPOSITE RUDDERS – FIRST YEAR

		FLIGHT TIME ACCUMULATIONS (HOURS)																							
		1976														1977									
		JUN		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
OPERATOR AND FUSELAGE NO.	INSTALLATION DATE	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
AIR SIAM/KOREAN NO. 125	6/16/76	152	152	324	476	328	804	323	1127	345	1472	74	1546	0	1546	0	1546	0	1546	226	1772	312	2084	370	2454	380	2834
WESTERN NO. 222	6/23/76	97	97	352	449	370	819	346	1165	336	1501	344	1845	370	2215	375	2590	329	2919	388	3307	352	3659	370	4029	345	4374
AIR NEW ZEALAND NO. 69	9/1/76	0	30*	0	30	0	30	260	290	400	690	377	1067	1409	1476	405	1881	353	2234	356	2590	401	2991	265	3256	425	3681
TRANS INTERNATIONAL NO. 96	1/18/77															52	52	221	273	230	503	300	803	286	1089	365	1454
TRANS INTERNATIONAL NO. 103	1/28/77																	199	199	215	414	270	684	346	1030	341	1371
TRANS INTERNATIONAL NO. 110	2/10/77																	79	79	228	307	287	594	282	876	394	1270
TOTALS		249	279	676	955	698	1653	929	2582	1056	3663	795	4458	779	5237	832	6069	1181	7250	1643	8893	1922	10,815	1919	12,734	2250	14,984

*30 HOURS ACCUMULATED DURING DOUGLAS FLIGHT TESTS

TABLE 2
FLIGHT-TIME ACCUMULATIONS FOR DC-10 GRAPHITE COMPOSITE RUDDERS – SECOND YEAR

OPERATOR AND FUSELAGE NO	INSTALLATION DATE	FLIGHT TIME ACCUMULATIONS (HOURS)																							
		1977												1978											
		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
		MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
KOREAN NO 125	6/16/76	424	3,258	411	3,669	342	4,011	393	4,404	366	4,770	379	5,149	199	5,348	265	5,613	352	5,965	339	6,304	329	6,633	371	7004
WESTERN NO 222	6/23/76	371	4,745	369	5,114	366	5,480	380	5,860	362	6,222	363	6,585	369	6,954	338	7,292	370	7,662	356	8,018	329	8,347	311	8658
AIR NEW ZEALAND NO 69	9/01/76	195	3,876	421	4,297	356	4,653	446	5,099	428	5,527	354	5,881	349	6,230	348	6,578	339	6,917	366	7,283	313	7,596	347	7943
TRANS-INTERNATIONAL NO 96	1/18/77	375	1,829	376	2,205	115	2,320	0	2,320	0	2,320	105	2,425	185	2,610	252	2,862	290	3,152	211	3,363	244	3,607	270	3877
TRANS-INTERNATIONAL NO 103	1/28/77	357	1,728	377	2,105	224	2,329	155	2,484	237	2,721	240	2,961	189	3,150	252	3,402	313	3,715	308	4,023	284	4,307	299	4606
TRANS INTERNATIONAL NO 110	2/10/77	386	1,656	395	2,051	82	2,133	0	2,133	0	2,133	127	2,260	280	2,540	279	2,819	303	3,122	288	3,410	271	3,681	333	4014
AIR NEW ZEALAND NO 116	7/13/77	221	221	357	578	407	985	406	1,391	355	1,746	324	2,070	374	2,444	299	2,743	337	3,080	348	3,428	332	3,760	341	4101
SWISSAIR NO 241	7/21/77							55	55	340	395	367	762	391	1,153	329	1,482	385	1,867	371	2,238	377	2,615	377	2992
TOTALS		2329	17,313	2706	20,019	1892	21,911	1835	23,746	2088	25,834	2259	28,093	2336	30,429	2362	32,791	2689	35,480	2587	38,067	2479	40,546	2649	43,195

TABLE 3
FLIGHT-TIME ACCUMULATIONS FOR DC-10 GRAPHITE COMPOSITE RUDDERS – THIRD YEAR

OPERATOR AND FUSELAGE NO.	INSTALLATION DATE	FLIGHT TIME ACCUMULATIONS (HOURS)																							
		1978												1979											
		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
		MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
KOREAN NO 125	6/16/76	299	7,303	330	7,633	292	7,925	272	8,197	322	8,519	357	8,876	335	9,211	340	9,551	344	9,895	369	10,264	286	10,550	79	10,629
WESTERN NO 222	6/23/76	398	9,056	389	9,445	359	9,804	372	10,176	372	10,548	363	10,911	383	11,294	300	11,594	358	11,952	370	12,322	361	12,683	57	12,740
AIR NEW ZEALAND NO 69	9/01/76	396	8,339	370	8,709	364	9,073	387	9,460	301	9,761	378	10,139	383	10,522	377	10,899	262	11,161	419	11,580	359	11,939	90	12,029
TRANS-INTERNATIONAL NO 96	1/18/77	391	4,268	308	4,576	375	4,951	346	5,297	262	5,559	171	5,730	272	6,002	290	6,292	143	6,435	270	6,705	293	6,998	79	7,077
TRANS-INTERNATIONAL NO 103	1/28/77	363	4,969	364	5,333	303	5,636	377	6,013	325	6,338	251	6,589	297	6,886	284	7,170	321	7,491	338	7,829	239	8,068	60	8,128
TRANS-INTERNATIONAL NO 110	2/10/77	398	4,412	395	4,807	308	5,115	288	5,403	321	5,724	225	5,949	276	6,225	289	6,514	329	6,843	260	7,103	295	7,398	65	7,463
AIR NEW ZEALAND NO 116	7/13/77	360	4,461	366	4,827	350	5,177	335	5,512	307	5,819	462	6,281	415	6,696	334	7,030	384	7,414	382	7,796	386	8,182	158	8,340
SWISSAIR NO 241	7/21/77	343	3,335	400	3,735	345	4,080	375	4,455	370	4,825	419	5,244	401	5,645	355	6,000	328	6,328	380	6,708	376	7,084	125	7,209
AIR NEW ZEALAND NO 213	11/22/78									68	68	371	439	375	814	260	1,074	382	1,456	378	1,834	337	2,171	77	2,248
TOTAL		2948	46,143	2922	49,605	2696	51,761	2752	54,513	2648	57,161	2997	60,158	3137	63,295	2829	66,124	2851	68,975	3166	72,141	2932	75,073	790	75,863

TABLE 4

FLIGHT-TIME ACCUMULATIONS FOR DC-10 COMPOSITE RUDDERS – FOURTH YEAR

OPERATOR AND FUSELAGE NO.	START SERVICE DATE	FLIGHT-TIME ACCUMULATIONS (HOURS)																							
		1979												1980											
		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
		MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
KOREAN NO. 125	6/16/76	248	10,877	276	11,153	272	11,425	293	11,718	316	12,034	301	12,335	307	12,642	321	12,963	291	13,254	241	13,495	349	13,844	265	14,109
WESTERN NO. 222	6/23/76	242	12,982	398	13,380	331	13,711	139	13,850	336	14,186	370	14,556	389	14,945	328	15,273	359	15,632	364	15,996	337	16,333	355	16,688
AIR NEW ZEALAND NO. 69	9/1/76	251	12,280	399	12,679	354	13,033	426	13,459	385	13,844	381	14,225	403	14,628	383	15,011	214	15,225	371	15,596	399	15,995	422	16,417
TRANSAMERICA NO. 96	1/18/77	231	7,308	282	7,690	311	8,001	328	8,329	280	8,609	131	8,740	106	8,846	148	8,994	106	9,100	84	9,184	179	9,363	72	9,435
TRANSAMERICA NO. 103	1/28/77	107	8,235	386	8,621	326	8,947	366	9,313	274	9,587	206	9,793	103	9,896	122	10,018	157	10,175	10	10,185	158	10,343	248	10,591
TRANSAMERICA NO. 110	2/10/77	191	7,654	394	8,048	287	8,335	333	8,668	220	8,888	164	9,052	72	9,124	53	9,177	183	9,360	114	9,474	219	9,693	253	9,946
AIR NEW ZEALAND NO. 116	7/13/77	248	8,588	388	8,976	406	9,382	428	9,810	356	10,166	439	10,605	392	10,997	418	11,415	228	11,643	400	12,043	357	12,400	380	12,780
SWISSAIR NO. 241	7/21/77	362	7,571	354	7,925	331	8,256	405	8,661	382	9,043	401	9,444	368	9,812	356	10,168	391	10,559	360	10,919	407	11,326	348	11,674
AIR NEW ZEALAND NO. 213	11/22/78	231	2,479	363	2,842	384	3,226	351	3,577	345	3,922	382	4,304	372	4,676	392	5,068	456	5,524	412	5,936	415	6,351	387	6,738
SWISSAIR NO. 293	2/1/80	–	–	–	–	–	–	–	–	–	–	–	–	11*	11*	171	182	313	495	372	867	369	1,236	329	1,565
SWISSAIR NO. 292	3/3/80	–	–	–	–	–	–	–	–	–	–	33*	33*	12*	45*	14*	59*	227	286	374	660	373	1,033	332	1,365
AIR NEW ZEALAND NO. 227	4/10/80	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	274	274	378	652	374	1,026
TOTAL		2111	77,974	3340	81,314	3002	84,316	3069	87,385	2894	90,279	2808	93,087	2535	95,622	2706	98,328	2925	101,253	3376	104,629	3940	108,569	3765	112,334

*DOUGLAS FLIGHT TEST

TABLE 5
FLIGHT-TIME ACCUMULATIONS FOR DC-10 GRAPHITE COMPOSITE RUDDERS – FIFTH YEAR

OPERATOR AND FUSELAGE NO.	START SERVICE DATE	FLIGHT-TIME ACCUMULATIONS (HOURS)																							
		1980												1981											
		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
		MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
KOREAN NO. 125	6/16/76	364	14,473	342	14,815	355	15,170	288	15,458	400	15,858	329	16,187	312	16,499	303	16,802	249	17,051	330	17,381	272	17,653	245	17,898
WESTERN NO. 222	6/23/76	342	17,030	339	17,369	320	17,689	284	17,973	260	18,233	304	18,537	284	18,821	113	18,934	281	19,215	262	19,477	227	19,704	284	19,988
AIR NEW ZEALAND NO. 69	9/1/76	401	16,818	289	17,207	344	17,551	379	17,930	383	18,313	393	18,706	363	19,069	186	19,255	244	19,499	367	19,866	419	20,285	299	20,584
TRANSAMERICA NO. 96	1/18/77	256	9,691	275	9,966	242	10,208	289	10,479	149	10,646	51	10,697	128	10,825	130	10,955	43	10,988	380	11,378	405	11,783	386	12,169
TRANSAMERICA NO. 103	1/28/77	258	10,849	198	11,047	274	11,321	367	11,688	290	11,978	110	12,088	152	12,240	13	12,253	116	12,369	117	12,486	310	12,796	326	13,122
TRANSAMERICA NO. 110	2/10/77	259	10,205	270	10,475	237	10,712	312	11,024	149	11,173	108	11,281	129	11,410	129	11,539	121	11,660	151	11,811	48	11,859	311	12,170
AIR NEW ZEALAND NO. 116	7/13/77	424	13,204	321	13,525	356	13,881	384	14,265	386	14,651	381	15,032	377	15,409	332	15,741	273	16,014	393	16,407	460	16,867	341	17,208
SWISSAIR NO. 241	7/21/77	398	12,072	357	12,429	383	12,812	359	13,171	394	13,565	343	13,908	387	14,295	331	14,626	311	14,937	387	15,324	372	15,696	364	16,060
AIR NEW ZEALAND NO. 213	11/22/78	399	7,137	381	7,518	385	7,903	336	8,239	289	8,528	406	8,934	393	9,327	339	9,666	347	10,013	408	10,421	402	10,823	347	11,170
SWISSAIR NO. 293	2/1/80	372	1,937	389	2,326	373	2,699	370	3,069	337	3,406	363	3,769	344	4,113	341	4,454	345	4,799	337	5,136	407	5,543	361	5,904
SWISSAIR NO. 292	3/3/80	356	1,721	405	2,126	339	2,465	335	2,800	373	3,173	286	3,459	350	3,809	351	4,160	367	4,527	360	4,887	356	5,243	377	5,620
AIR NEW ZEALAND NO. 227	4/10/80	417	1,443	425	1,868	415	2,283	342	2,625	208	2,833	335	3,168	429	3,597	287	3,884	398	4,282	404	4,686	411	5,097	347	5,444
TOTAL		4246	116,580	4091	120,671	4023	124,694	4045	128,739	3618	132,357	3409	135,766	3648	139,414	2852	142,269	3095	145,364	3896	149,260	4089	153,349	3988	157,337

TABLE 6

FLIGHT-TIME ACCUMULATIONS FOR DC-10 GRAPHITE COMPOSITE RUDDERS – SIXTH YEAR

OPERATOR AND FUSELAGE NO.	SERVICE START DATE	FLIGHT-TIME ACCUMULATIONS (HOURS)																							
		1981												1982											
		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
		MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
KOREAN NO. 125	6/16/76	335	18,233	281	18,514	287	18,801	218	19,019	285	19,304	232	19,536	239	19,775	286	20,061	308	20,369	266	20,635	262	20,897	228	21,125
WESTERN NO. 222	6/23/76	350	20,338	290	20,628	228	20,856	279	21,135	63	21,198	269	21,467	218	21,685	0	21,685	0	21,685	0	21,685	0	21,685	0	21,685
AIR NEW ZEALAND NO. 69	9/1/76	139	20,723	156	20,879	205	21,084	152	21,236	154	21,390	199	21,589	179	21,768	196	21,964	155	22,119	146	22,265	0	22,265	0	22,265
TRANSAMERICA NO. 96	1/18/77	486	12,655	431	13,086	187	13,273	27	13,300	270	13,570	162	13,732	121	13,853	187	14,040	268	14,308	247	14,555	225	14,780	275	15,055
TRANSAMERICA NO. 103	1/28/77	372	13,494	435	13,929	356	14,285	435	14,720	163	14,883	213	15,096	287	15,383	170	15,553	187	15,740	262	16,002	282	16,284	235	16,519
TRANSAMERICA NO. 110	2/10/77	270	12,440	301	12,741	328	13,069	353	13,422	145	13,567	51	13,618	36	13,654	80	13,734	84	13,818	53	13,871	54	13,925	215	14,140
AIR NEW ZEALAND NO. 116	7/13/77	147	17,355	0	17,355	0	17,355	0	17,355	0	17,355	0	17,355	0	17,355	0	17,355	0	17,355	0	17,355	113	17,468	246	17,714
SWISSAIR NO. 241	7/21/77	361	16,421	357	16,778	361	17,139	408	17,547	393	17,940	399	18,339	342	18,681	312	18,993	378	19,371	358	19,729	357	20,086	374	20,460
AIR NEW ZEALAND NO. 213	11/22/78	243	11,413	115	11,528	101	11,629	0	11,629	0	11,629	0	11,629	0	11,629	0	11,629	0	11,629	0	11,629	38	11,667	188	11,855
SWISSAIR NO. 293	2/1/80	369	6,273	390	6,663	353	7,016	346	7,362	364	7,726	344	8,070	386	8,456	380	8,836	368	9,204	356	9,560	378	9,938	345	10,283
SWISSAIR NO. 292	3/3/80	355	5,975	360	6,335	394	6,729	346	7,075	138	7,213	331	7,544	335	7,879	325	8,204	353	8,557	356	8,913	358	9,271	355	9,626
AIR NEW ZEALAND NO. 227	4/10/80	289	5,733	185	5,918	246	6,164	246	6,410	131	6,541	154	6,695	221	6,916	158	7,074	154	7,228	113	7,341	173	7,514	0	7,514
CONTINENTAL NO. 101	11/25/81									30	30	284	314	255	569	200	769	143	912	151	1,063	191	1,254	202	1,456
TOTALS		3,716	161,053	3,301	164,354	3,046	167,400	2,810	170,210	2,136	172,346	2,638	174,984	2,619	177,603	2,294	179,897	2,398	182,295	2,308	184,603	2,431	187,034	2,663	189,697

TABLE 7

FLIGHT-TIME ACCUMULATIONS FOR DC-10 COMPOSITE RUDDERS – SEVENTH YEAR

OPERATOR RUDDER SERIAL NO. AND FUSELAGE NO.	START SERVICE DATE	FLIGHT-TIME ACCUMULATIONS (HOURS)																							
		1982												1983											
		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
		MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
KOREAN SERIAL NO 3 FUSELAGE NO 125	6/16/76	358	21,483	243	21,726	252	21,978	245	22,223	222	22,445	291	22,736	180	22,916	180	23,096	180	23,276	190	23,466	276	23,742	211	23,953
WESTERN (1) SERIAL NO 2 FUSELAGE NO 222	6/23/76	0	21,685	0	21,685	0	21,685	0	21,685	0	21,685	176	21,861	296	22,157	280	22,437	332	22,769	265	23,034	370	23,404	341	23,745
AIR NEW ZEALAND (2) SERIAL NO 4 FUSELAGE NO 69	9/1/76	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265
TRANSAMERICA (3) SERIAL NO 10 FUSELAGE NO 96	1/18/77	338	15,393	332	15,725	286	16,011	99	16,110	0	16,110	0	16,110	0	16,110	0	16,110	0	16,110	0	16,110	0	16,110	0	16,110
TRANSAMERICA (3) SERIAL NO 9 FUSELAGE NO 103	1/28/77	359	16,878	376	17,254	307	17,561	446	18,007	403	18,410	387	18,797	426	19,223	83	19,306	0	19,306	0	19,306	0	19,306	0	19,306
TRANSAMERICA (3) SERIAL NO 1 FUSELAGE NO 110	2/10/77	357	14,497	381	14,878	192	15,070	57	15,127	0	15,127	0	15,127	0	15,127	0	15,127	0	15,127	0	15,127	0	15,127	0	15,127
AIR NEW ZEALAND (4) SERIAL NO 5 FUSELAGE NO 116/69	7/13/77	200	17,914	196	18,110	191	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301
SWISSAIR SERIAL NO 8 FUSELAGE NO 241	7/21/77	373	20,833	127	20,960	348	21,308	370	21,678	369	22,047	333	22,380	337	22,717	350	23,067	366	23,433	327	23,760	338	24,098	324	24,422
MOZAMBIQUE SERIAL NO 6 FUSELAGE NO 213	11/22/78	223	12,078	222	12,300	211	12,511	264	12,775	14	12,789	22	12,811	31	12,842	206	13,048	206	13,254	219	13,473	234	13,707	223	13,930
SWISSAIR (5) SERIAL NO 11 FUSELAGE NO 293/132	2/1/80	33	10,316	0	10,316	204	10,520	388	10,908	365	11,273	363	11,636	329	11,965	304	12,269	380	12,649	338	12,987	340	13,327	304	13,631
SWISSAIR (5) SERIAL NO 12 FUSELAGE NO 292/184	3/3/80	152	9,778	0	9,778	0	9,778	277	10,055	367	10,422	379	10,801	412	11,213	328	11,541	349	11,890	325	12,215	358	12,573	325	12,898
AIR NEW ZEALAND SERIAL NO 7 FUSELAGE NO 227	4/10/80	350	7,894	350	8,244	300	8,544	314	8,858	298	9,156	360	9,516	335	9,851	294	10,145	239	10,384	265	10,649	272	10,921	240	11,161
CONTINENTAL SERIAL NO 13 FUSELAGE NO 101	11/25/81	259	1,715	259	1,974	249	2,223	236	2,459	224	2,683	251	2,934	243	3,177	122	3,299	140	3,439	73	3,512	135	3,647	222	3,869
TOTAL		3,002	192,729	2,486	195,215	2,540	197,755	2,696	200,451	2,262	202,713	2,562	205,275	2,589	207,864	2,147	210,011	2,192	212,203	2,002	214,205	2,323	216,528	2,190	218,718

NOTES:

(1) WESTERN AIRLINES RUDDER WAS RETURNED TO SERVICE AFTER DAMAGE REPAIR ON 12 DECEMBER 1982.

(2) AIR NEW ZEALAND RUDDER SERIAL NO. 4 WAS REMOVED FROM SERVICE IN APRIL 1982 FOR ADDITIONAL GROUND TESTS.

(3) TRANSAMERICA AIRCRAFT ARE IN TEMPORARY STORAGE AS OF THE FOLLOWING DATES:

FUSELAGE NO. 96: 5 OCTOBER 1982
FUSELAGE NO. 103: 24 FEBRUARY 1983
FUSELAGE NO. 110: 6 OCTOBER 1982

(4) AIR NEW ZEALAND RUDDER SERIAL NO. 5 WAS REMOVED FROM SERVICE IN SEPTEMBER 1982 WHEN THE AIRCRAFT WAS SOLD.

(5) SWISSAIR MADE THE FOLLOWING CHANGES:

REMOVED SERIAL NO. 11 FROM FUSELAGE NO. 293 ON 16 JULY 1982 AND INSTALLED IT ON FUSELAGE NO. 132 ON 14 SEPTEMBER 1982
REMOVED SERIAL NO. 12 FROM FUSELAGE NO. 292 ON 30 JULY 1982 AND INSTALLED IT ON FUSELAGE NO. 184 ON 2 OCTOBER 1982

TABLE 8
FLIGHT-TIME ACCUMULATIONS FOR DC-10 COMPOSITE RUDDERS – EIGHTH YEAR

OPERATOR RUDDER SERIAL NO. AND FUSELAGE NO.	START SERVICE DATE	FLIGHT-TIME ACCUMULATIONS (HOURS)																							
		1983												1984											
		JUL		AUG		SEP		OCT		NOV		DEC		JAN		FEB		MAR		APR		MAY		JUN	
		MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM	MO	CUM
KOREAN SERIAL NO. 3 FUSELAGE NO. 125	6/16/76	279	24,223	216	24,439	286	24,725	284	25,009	236	25,245	242	25,487	273	25,760	295	26,055	283	26,338	265	26,603	271	26,874	292	27,166
WESTERN (1) SERIAL NO. 2 FUSELAGE NO. 222	6/23/76	360	24,105	294	24,399	257	24,656	271	24,927	292	25,219	311	25,530	0	25,530	0	25,530	57	25,587	229	25,816	213	26,029	303	26,332
AIR NEW ZEALAND (2) SERIAL NO. 4 FUSELAGE NO. 69	9/1/76	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265
FEDERAL EXPRESS (3) SERIAL NO. 10 FUSELAGE NO. 96	1/18/77	0	16,020	0	16,020	0	16,020	0	16,020	15	16,035	72	16,107	76	16,183	67	16,250	0	16,250	53	16,303	79	16,382	53	16,435
FEDERAL EXPRESS (3) SERIAL NO. 9 FUSELAGE NO. 103	1/28/77	0	19,306	0	19,306	0	19,306	0	19,306	0	19,306	0	19,306	0	19,306	0	19,306	24	19,330	41	19,371	148	19,519	76	19,595
FEDERAL EXPRESS (3) SERIAL NO. 1 FUSELAGE NO. 110	2/10/77	0	15,127	0	15,127	0	15,127	0	15,127	0	15,127	0	15,127	0	15,127	0	15,127	82	15,209	68	15,277	94	15,371	106	15,477
AIR NEW ZEALAND (4) SERIAL NO 5 FUSELAGE NO. 116/96	7/13/77	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301
SWISSAIR SERIAL NO. 8 FUSELAGE NO. 241	7/21/77	323	24,745	352	25,097	376	25,473	344	25,817	287	26,104	229	26,333	296	26,629	314	26,943	361	27,304	313	27,617	307	27,924	246	28,170
MOZAMBIQUE SERIAL NO. 6 FUSELAGE NO. 213	11/22/78	271	14,201	287	14,488	268	14,756	188	14,944	210	15,154	197	15,351	187	15,538	186	15,724	228	15,952	212	16,164	178	16,342	192	16,534
SWISSAIR SERIAL NO. 11 FUSELAGE NO. 293/132	2/1/80	350	13,981	332	14,313	326	14,639	358	14,997	257	15,254	296	15,550	349	15,899	304	16,203	424	16,627	371	16,998	289	17,287	304	17,591
SWISSAIR SERIAL NO. 12 FUSELAGE NO. 292/184	3/3/80	394	13,292	376	13,668	361	14,029	325	14,354	306	14,660	340	15,000	347	15,347	321	15,668	343	16,011	285	16,296	296	16,592	332	16,924
AIR NEW ZEALAND SERIAL NO. 7 FUSELAGE NO. 227	4/10/80	223	11,384	245	11,629	223	11,852	225	12,077	222	12,299	230	12,529	220	12,749	213	12,962	236	13,198	244	13,442	226	13,668	244	13,912
CONTINENTAL SERIAL NO. 13 FUSELAGE NO. 101	11/25/81	211	4,080	212	4,292	183	4,475	0	4,475	19	4,494	57	4,551	63	4,614	104	4,718	193	4,911	264	5,175	249	5,424	220	5,644
SWISSAIR (5) SERIAL NO. 14 FUSELAGE NO. 187	6/1/83	323	349	405	754	324	1,078	332	1,410	263	1,673	330	2,003	340	2,343	307	2,650	332	2,982	299	3,281	353	3,634	323	3,957
TOTALS		2,725	221,379	2,719	224,098	2,604	226,702	2,327	229,029	2,107	231,136	2,304	233,440	2,151	235,591	2,111	237,702	2,563	240,265	2,644	242,909	2,703	245,612	2,677	248,289

(1) RUDDER SERIAL NO. 2 WAS REMOVED FROM SERVICE ON 22 DECEMBER 1983 FOR NONDESTRUCTIVE INSPECTION AND RETURNED TO SERVICE ON 24 MARCH 1984

(2) RUDDER SERIAL NO. 4 WAS PERMANENTLY REMOVED FROM SERVICE IN APRIL 1982 FOR ADDITIONAL GROUND TESTS

(3) FEDERAL EXPRESS STARTED OPERATIONS WITH THESE AIRCRAFT ON THE FOLLOWING DATES
- FUSELAGE NO. 96 NOVEMBER 1983
- FUSELAGE NO. 103 MARCH 1984
- FUSELAGE NO. 110 MARCH 1984

(4) RUDDER SERIAL NO. 5 WAS PERMANENTLY REMOVED FROM SERVICE IN SEPTEMBER 1982 WHEN THE AIRCRAFT WAS SOLD

(5) RUDDER SERIAL NO. 14 STARTED FLIGHT SERVICES 29 JUNE 1983

TABLE 9

FLIGHT-TIME ACCUMULATIONS FOR DC-10 COMPOSITE RUDDERS – NINTH YEAR

OPERATOR RUDDER SERIAL NO. FUSELAGE NO.	START SERVICE DATE	FLIGHT-TIME ACCUMULATIONS (HOURS) 1984 JUL MO	JUL CUM	AUG MO	AUG CUM	SEP MO	SEP CUM	OCT MO	OCT CUM	NOV MO	NOV CUM	DEC MO	DEC CUM	1985 JAN MO	JAN CUM	FEB MO	FEB CUM	MAR MO	MAR CUM	APR MO	APR CUM	MAY MO	MAY CUM	JUN MO	JUN CUM
KOREAN SERIAL NO. 3 FUSELAGE NO. 125	6/16/76	302	27,468	282	27,750	298	28,048	246	28,294	267	28,561	308	28,869	324	29,193	206	29,399	306	29,705	328	30,033	254	30,287	287	30,574
WESTERN (1) SERIAL NO. 2 FUSELAGE NO. 222	6/23/76	364	26,696	165	26,861	0	26,861	0	26,861	0	26,861	0	26,861	0	26,861	0	26,861	0	26,861	0	26,861	0	26,861	0	26,861
AIR NEW ZEALAND (2) SERIAL NO. 4 FUSELAGE NO. 69	9/1/76	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265	0	22,265
FEDERAL EXPRESS SERIAL NO. 10 FUSELAGE NO. 96	1/18/77	74	16,509	106	16,661	84	16,699	124	16,823	122	16,945	92	17,037	78	17,115	67	17,182	104	17,286	103	17,389	131	17,514	103	17,617
FEDERAL EXPRESS SERIAL NO. 9 FUSELAGE NO. 103	1/28/77	58	19,653	64	19,717	107	19,824	124	19,948	105	20,053	104	20,157	100	20,257	75	20,332	92	20,424	126	20,550	100	20,650	100	20,750
FEDERAL EXPRESS SERIAL NO. 1 FUSELAGE NO. 110	2/10/77	105	15,582	80	15,662	97	15,759	105	15,864	94	15,958	96	16,054	121	16,175	55	16,230	100	16,330	110	16,440	153	16,593	163	16,756
FINNAIR (3) SERIAL NO. 5 FUSELAGE NO. 201	5/1/85	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	0	18,301	99	19,000	407	19,407
SWISSAIR SERIAL NO. 8 FUSELAGE NO. 241	7/21/77	363	28,533	309	28,842	359	29,201	300	29,501	334	29,835	254	30,089	344	30,433	315	30,748	358	31,106	336	31,442	350	31,792	341	32,133
MOZAMBIQUE SERIAL NO. 6 FUSELAGE NO. 213	11/22/78	180	16,714	271	16,985	265	17,250	197	17,447	196	17,643	217	17,860	216	18,076	151	18,227	231	18,458	222	18,680	200	18,880	192	19,072
SWISSAIR SERIAL NO. 11 FUSELAGE NO. 293/132	2/1/80	325	17,916	359	18,275	349	18,624	289	18,913	320	19,233	350	19,583	388	19,971	260	20,231	348	20,579	206	20,785	382	21,167	374	21,541
SWISSAIR SERIAL NO. 12 FUSELAGE NO. 292/184	3/3/80	294	17,218	350	17,568	351	17,919	359	18,278	278	18,556	311	18,867	342	19,209	191	19,400	366	19,766	361	20,127	309	20,436	340	20,776
AIR NEW ZEALAND SERIAL NO. 7 FUSELAGE NO. 227	4/10/80	245	14,157	223	14,384	232	14,616	234	14,850	225	15,075	279	15,354	324	15,678	190	15,868	237	16,105	235	16,340	213	16,553	229	16,782
CONTINENTAL SERIAL NO. 13 FUSELAGE NO. 101	11/25/81	277	5,921	260	6,181	189	6,370	204	6,547	151	6,698	213	6,911	247	7,158	246	7,404	268	7,672	238	7,910	230	8,140	267	8,407
SWISSAIR SERIAL NO. 14 FUSELAGE NO. 187	6/1/83	345	4,302	267	4,569	342	4,911	273	5,184	369	5,553	263	5,816	349	6,165	330	6,495	337	6,832	399	7,231	363	7,594	333	7,927
WESTERN (4) SERIAL NO. 15 FUSELAGE NO. 322	3/1/85	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	74	74	275	349	355	704	335	1,039
TOTALS		2,932	251,235	2,736	253,971	2,673	256,644	2,455	259,076	2,461	261,537	2,487	264,024	2,833	266,857	2,086	268,943	2,821	271,764	2,939	274,703	3,139	278,436	3,471	281,907

1 RUDDER SERIAL NO. 2 WAS REMOVED FROM SERVICE IN AUGUST 1984 DUE TO LIGHTNING STRIKE DAMAGE. THE RUDDER WILL BE REPAIRED AND RETURNED TO SERVICE.

2 RUDDER SERIAL NO. 4 WAS PERMANENTLY REMOVED FROM SERIVCE IN APRIL 1982 FOR ADDITIONAL GROUND TESTS.

3 RUDDER SERIAL NO. 5 WAS REMOVED FROM AIR NEW ZEALAND FUSELAGE NO. 116 IN SEPTEMBER 1982 AND WAS INSTALLED ON FINNAIR FUSELAGE NO. 201 ON MAY 24, 1985.

4 RUDDER SERIAL NO. 15 WAS PLACED IN FLIGHT SERVICE ON MARCH 20, 1985.

TABLE 10

SUMMARY OF IN-SERVICE INSPECTION RESULTS

FUSELAGE NO.	OPERATOR	TYPE OF INSPECTION	INSPECTION PERSONNEL	DATE INSPECTION	FLIGHT HOURS ON RUDDER	REMARKS
69	AIR NEW ZEALAND	ULTRASONIC	ANZ	3 MAY 77	2,948	DETECTED 3 MINOR BOND DEFECTS
		ULTRASONIC	ANZ	31 MAY 77	3,252	RECHECK OF 3 MAY 77 RESULTS
		ULTRASONIC	DOUGLAS	28 JUNE 77	3,600	RECHECK OF 3 MAY 77 RESULTS
		ULTRASONIC	ANZ	25 MAY 77	7,519	NO CHANGE
		ULTRASONIC	ANZ	7 NOV 78	9,465	NO CHANGE
		ULTRASONIC	ANZ	9 JAN 79	10,200	DISBOND GROWTH INDICATED, ONE PLACE
		ULTRASONIC	ANZ	8 JAN 80	14,325	NO CHANGE
		ULTRASONIC	ANZ	7 AUG 80	16,881	RH UPPER SEGMENT INSPECTED. NO CHANGE
		ULTRASONIC	ANZ	2 SEP 80	17,211	RH LOWER SEGMENT INSPECTED NO DISBOND GROWTH. MINOR LIGHTNING DAMAGE OBSERVED
		ULTRASONIC	ANZ	9 OCT 80	17,273	LH UPPER SEGMENT INSPECTED. NO CHANGE
		ULTRASONIC	ANZ	4 MAR 81	19,256	LH LOWER SEGMENT INSPECTED. NO CHANGE
		ULTRASONIC	ANZ	5 MAY 81	19,926	RH LOWER SEGMENT INSPECTED. NO CHANGE
		ULTRASONIC	ANZ	9 JUN 81	20,390	LH UPPER SEGMENT INSPECTED. NO CHANGE
		ULTRASONIC	ANZ	6 MAY 82	22,265	NO CHANGE. RUDDER REMOVED FROM FLIGHT-SERVICE FOR GROUND TESTS.
		ULTRASONIC	DOUGLAS	MAR 83	22,265	DAC INSPECTION PRIOR TO GROUND TEST
96	TRANSAMERICA	ULTRASONIC	DOUGLAS	31 JAN 78	2,610	NO DEFECTS
		ULTRASONIC	DOUGLAS	16 JAN 79	5,840	NO DEFECTS
		VISUAL	DOUGLAS	6 MAY 79	6,745	PAINT CHIPS ON F/G LEADING EDGE
		ULTRASONIC	DOUGLAS	16 JAN 80	8,807	NO DEFECTS
		ULTRASONIC	DOUGLAS	11 JUN 80	9,419	NO DEFECTS
		ULTRASONIC	DOUGLAS	18 DEC 80	10,677	NO DISBOND DEFECTS
	AIR FLORIDA	ULTRASONIC	DOUGLAS	7 APR 82	14,473	NO CHANGE
103	TRANSAMERICA	ULTRASONIC	DOUGLAS	11 JAN 78	3,016	NO DEFECTS
		ULTRASONIC	DOUGLAS	18 DEC 78	6,508	NO DEFECTS
		ULTRASONIC	DOUGLAS	18 DEC 79	9,751	MISCELLANEOUS PAINT CHIPS
		ULTRASONIC	DOUGLAS	27 JAN 81	12,228	NO DEFECTS
	AIR FLORIDA	ULTRASONIC	DOUGLAS	5 APR 82	15,762	NO DEFECTS
		ULTRASONIC	DOUGLAS	15 DEC 82	18,521	NO DEFECTS
110	TRANSAMERICA	ULTRASONIC	DOUGLAS	18 MAR 77	200	NO DEFECTS
		ULTRASONIC	DOUGLAS	22 FEB 78	2,758	NO DEFECTS
		ULTRASONIC	DOUGLAS	29 JAN 79	6,224	NO DEFECTS
		ULTRASONIC	DOUGLAS	14 JAN 81	11,359	NO DEFECTS
		ULTRASONIC	DOUGLAS	8 DEC 81	13,566	DETECTED 2 MINOR BOND DEFECTS RIB 4, LH SIDE AND RIB 15, RH SIDE

TABLE 10

SUMMARY OF IN-SERVICE INSPECTION RESULTS (CONTINUED)

FUSELAGE NO.	OPERATOR	TYPE OF INSPECTION	INSPECTION PERSONNEL	DATE INSPECTION	FLIGHT HOURS ON RUDDER	REMARKS
116	AIR NEW ZEALAND	ULTRASONIC	ANZ	17 MAR 78	2,800	NO DEFECTS
		VISUAL	ANZ	25 MAY 78	3,563	NO DEFECTS
		ULTRASONIC	ANZ	1 NOV 78	5,512	SMALL BOND DEFECT, RIB 20, LH SIDE
		ULTRASONIC	ANZ	10 JAN 80	10,730	NO CHANGE
		ULTRASONIC	ANZ	17 MAR 80	11,547	NO CHANGE
		ULTRASONIC	ANZ	22 OCT 80	14,163	LH UPPER SEGMENT INSPECTED. NO CHANGE
		ULTRASONIC	ANZ	19 NOV 80	14,513	RH LOWER SEGMENT INSPECTED. NO CHANGE
		ULTRASONIC	ANZ	26 MAR 81	16,014	LH LOWER SEGMENT INSPECTED. NO CHANGE
		ULTRASONIC	ANZ	16 JUL 81	17,355	LH UPPER AND RH LOWER SEGMENTS. NO CHANGE
		ULTRASONIC	ANZ	3 MAY 82	17,355	NO CHANGE. RUDDER TRANSFERRED TO FUSELAGE NO. 69
125	KOREAN	VISUAL	DOUGLAS	21 DEC 76	1,500	NO DEFECTS
		ULTRASONIC	DOUGLAS	15 SEP 79	11,154	DETECTED 3 MINOR BOND DEFECTS
		ULTRASONIC	DOUGLAS	28 APR 83	23,466	RH SIDE INSPECTED. NO DEFECTS
187	SWISSAIR	ULTRASONIC	SWISSAIR	29 MAY 84	3,620	NO DEFECTS
		VISUAL	SWISSAIR	29 MAY 84	3,620	NO DEFECTS
213	AIR NEW ZEALAND	ULTRASONIC	ANZ	22 NOV 79	3,820	NO DEFECTS
		ULTRASONIC	ANZ	28 FEB 80	5,055	NO DEFECTS
		ULTRASONIC	ANZ	18 SEP 80	7,739	LH LOWER SEGMENT INSPECTED. NO DEFECTS
		ULTRASONIC	ANZ	28 OCT 80	8,239	LH UPPER SEGMENT INSPECTED. NO DEFECTS
		ULTRASONIC	ANZ	28 JAN 81	9,281	RH LOWER SEGMENT INSPECTED. NO DEFECTS
		ULTRASONIC	ANZ	31 MAR 81	10,012	RH UPPER SEGMENT INSPECTED. NO DEFECTS
		ULTRASONIC	ANZ	11 JUN 81	10,961	LH UPPER SEGMENT INSPECTED. NO DEFECTS
222	WESTERN	ULTRASONIC	DOUGLAS	2 MAR 77	3,000	NO DEFECTS
		ULTRASONIC	DOUGLAS	2 OCT 77	5,499	NO DEFECTS
		ULTRASONIC	DOUGLAS	2 MAY 78	8,028	NO DEFECTS
		ULTRASONIC	DOUGLAS	8 DEC 78	10,817	NO DEFECTS
		ULTRASONIC	DOUGLAS	28 JUL 79	12,930	NO DEFECTS
		ULTRASONIC	DOUGLAS	23 JUL 80	16,978	MISCELLANEOUS PAINT CHIPS AND CRACKS
		ULTRASONIC	DOUGLAS	22 JUL 81	20,222	MISCELLANEOUS PAINT CHIPS AND CRACKS
		ULTRASONIC	DOUGLAS	1 FEB 82	21,685	RIB NO. 8 LH FLANGE DISBONDED. RUDDER WAS REMOVED FROM AIRCRAFT FOR REPAIR
		ULTRASONIC	DOUGLAS	MAY 82	21,685	DAC INSPECTION OF DAMAGE
		ULTRASONIC	DOUGLAS	NOV 82	21,685	DAC INSPECTION OF REPAIR

TABLE 10

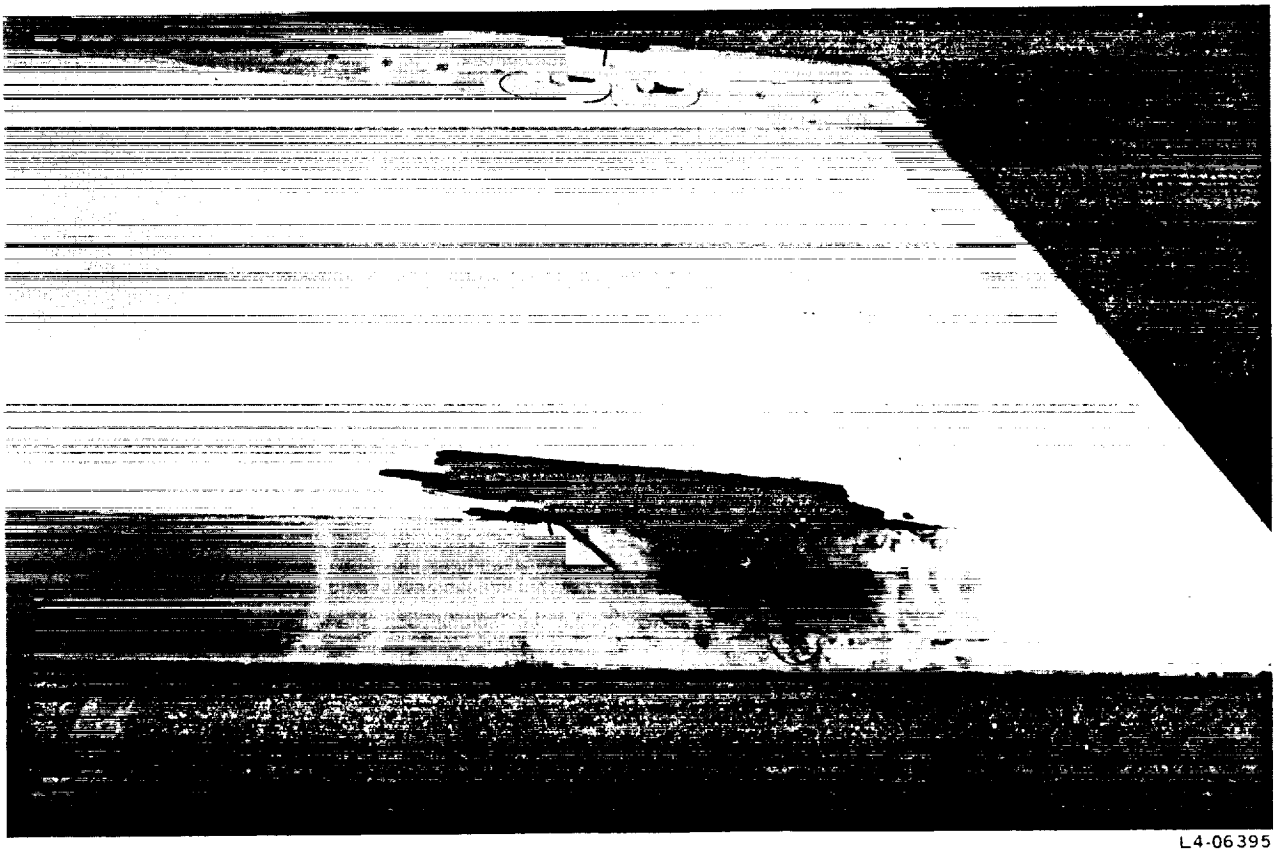
SUMMARY OF IN-SERVICE INSPECTION RESULTS (CONTINUED)

FUSELAGE NO.	OPERATOR	TYPE OF INSPECTION	INSPECTION PERSONNEL	DATE INSPECTION	FLIGHT HOURS ON RUDDER	REMARKS
227	AIR NEW ZEALAND	ULTRASONIC	ANZ	14 SEP 80	2,159	RH SEGMENT INSPECTED. NO DEFECTS
		ULTRASONIC	ANZ	26 JAN 81	3,635	LH UPPER SEGMENT INSPECTED. NO DEFECTS
		ULTRASONIC	ANZ	9 APR 81	4,472	LH LOWER SEGMENT INSPECTED. NO DEFECTS
		ULTRASONIC	ANZ	16 JUN 81	5,295	RH LOWER SEGMENT INSPECTED. NO DEFECTS
		ULTRASONIC	ANZ	7 SEP 81	5,958	LH UPPER SEGMENT INSPECTED. NO DEFECTS
241	SWISSAIR	ULTRASONIC	SWISSAIR	30 JUL 79	7,553	NO DEFECTS
		ULTRASONIC	SWISSAIR	13 OCT 80	12,962	NO DEFECTS
		VISUAL	SWISSAIR	8 JAN 81	15,770	NO DEFECTS
		ULTRASONIC	SWISSAIR	19 JUL 82	20,700	NO DEFECTS
		ULTRASONIC	SWISSAIR	10 JAN 83	22,473	NO DEFECTS
		VISUAL	SWISSAIR	5 APR 83	23,500	NO DEFECTS
		ULTRASONIC	SWISSAIR	5 JUL 83	24,474	NO DEFECTS
		VISUAL	SWISSAIR	10 MAY 84	27,694	NO DEFECTS
292	SWISSAIR	ULTRASONIC	SWISSAIR	2 FEB 81	3,829	NO DEFECTS
		VISUAL	SWISSAIR	23 APR 81	4,799	NO DEFECTS
		ULTRASONIC	SWISSAIR	11 JAN 82	7,590	NO DEFECTS
184 (EX 292)	SWISSAIR	ULTRASONIC	SWISSAIR	14 MAR 83	11,702	NO DEFECTS
		VISUAL	SWISSAIR	7 JUN 83	12,631	NO DEFECTS
		ULTRASONIC	SWISSAIR	6 MAR 84	15,738	NO DEFECTS
		VISUAL	SWISSAIR	21 JUN 84	16,820	NO DEFECTS
293	SWISSAIR	ULTRASONIC	SWISSAIR	1 DEC 80	3,404	NO DEFECTS
		VISUAL	SWISSAIR	18 MAY 81	5,360	NO DEFECTS
		ULTRASONIC	SWISSAIR	19 OCT 81	7,220	NO DEFECTS
132 (EX 293)	SWISSAIR	ULTRASONIC	SWISSAIR	24 JAN 83	11,874	NO DEFECTS
		VISUAL	SWISSAIR	20 APR 83	12,837	NO DEFECTS
		ULTRASONIC	SWISSAIR	23 JAN 84	15,809	NO DEFECTS
		VISUAL	SWISSAIR	31 JUL 84	17,915	NO DEFECTS

SECTION 3

RUDDER REPAIR

On August 17, 1984, composite rudder Serial No. 2 aboard Western Airlines fuselage 222 was struck by lightning while approaching San Francisco International Airport. The rudder was damaged in the upper aft tip region and had to be removed from the aircraft. The rudder had been in use for more than 27,000 hours at the time of removal. Incidentally, this is the same rudder that was repaired at Douglas after a rib disbonded, as reported in Reference 3. The damaged rudder is shown in Figure 1.

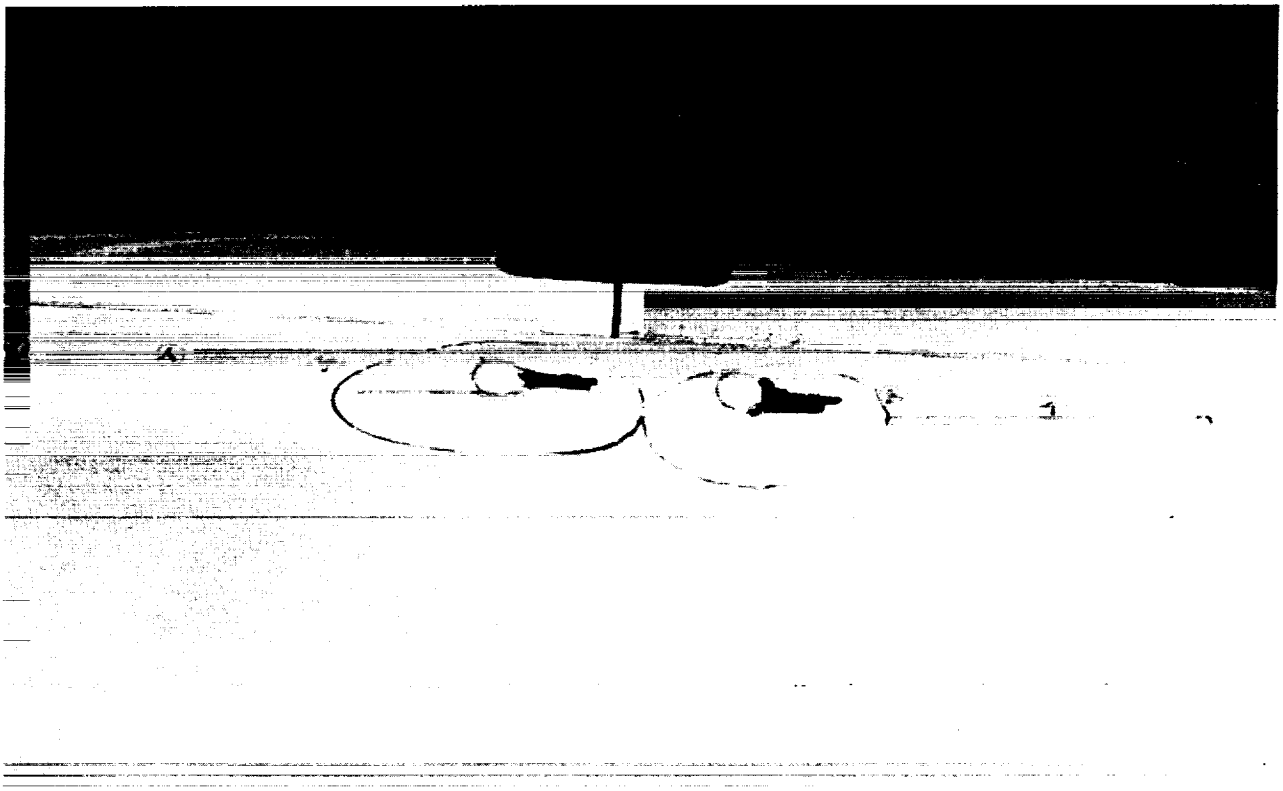


L4-06395

FIGURE 1. LIGHTNING STRIKE DAMAGE NEAR THE RUDDER UPPER TIP

The primary lightning protection system of the composite rudder consists of an aluminum strip which runs along the upper portion of the trailing edge and across the tip. This strip is connected to the metal forward rudder by a bounding strap. After the incident, an investigation disclosed that the lightning protection strap was inadvertently left off after the last maintenance check.

When the aircraft experienced the lightning strike, the current entered the rudder at the upper hinge. It arced from the hinge fitting into the carbon skins at the hinge attach bolts, causing a small amount of damage, as shown in Figure 2. The current then exited from the aircraft at the trailing edge of the composite box forward of the nonconductive fiberglass aerodynamic trailing edge, causing considerable damage, as shown in Figure 3. A close-up of the carbon rear spar damage with the fiberglass trailing edge removed is shown in Figure 4.

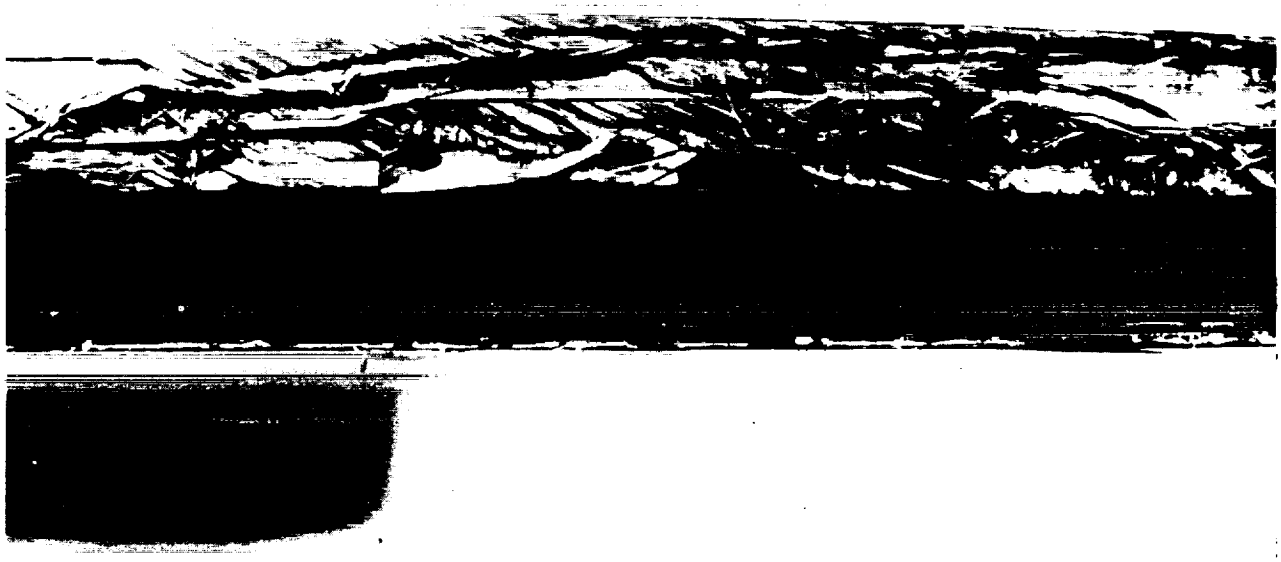


L4-06391

FIGURE 2. CURRENT TRANSFER DAMAGE AT THE HINGE FITTING ATTACH BOLTS

L4-06388

FIGURE 3. TRAILING EDGE EXIT DAMAGE



L4-06510

FIGURE 4. SKIN AND SPAR CAP DAMAGE

The skin in the damaged area consists of six plies of tape, for a thickness of about 0.033 inch. The skin is built up to eight plies over an eight-ply spar cap (0.88 inch total thickness). Fiber damage and resin vaporization extended all the way through the skin forward of the spar, and the skin and spar cap aft of the rear spar web were completely destroyed.

A number of options existed for repairing the rudder. A quick "boiler plate" repair using an external patch and existing repair technology was possible and would result in the rudder being returned to service in the shortest possible time. An autoclave repair was possible since Douglas has the necessary facilities and equipment to conduct this type of operation. Or a new, simplified repair technique could be developed that would be usable by airlines with limited facilities and in remote locations.

It was decided to develop and demonstrate a wet laminated repair procedure. The procedure developed is a nonautoclave repair technique using low cure temperatures and only vacuum pressure. The materials are storable at room temperature so that preimpregnated materials need not be refrigerated. The equipment is relatively simple and portable, and most airlines should be able to afford it. The technique uses dry carbon cloth which is impregnated with a resin system utilizing an aromatic amine curing agent at the repair site. The material used was Hercules AS4 carbon cloth and Hysol EA956 resin with the L3 catalyst. This sterically inhibited catalyst extends the resin working life from the normal 30 minutes to 7 hours. This is a necessary condition for this type of laminating technique since 30 minutes is not enough time to impregnate and lay-up the carbon cloth.

Early tests indicated that a wet laminated repair system would not have sufficient strength. However, the repair scarf geometry and processing conditions were developed until the repair strength was able to exceed the autoclave cured parent material strength, as shown in Figure 5. The material systems evaluated were Hysol EA956, EA9323, EA956 with an EA9321 adhesive interface, EA956 with BR127 primer, and Ciba Geigy CG1300.

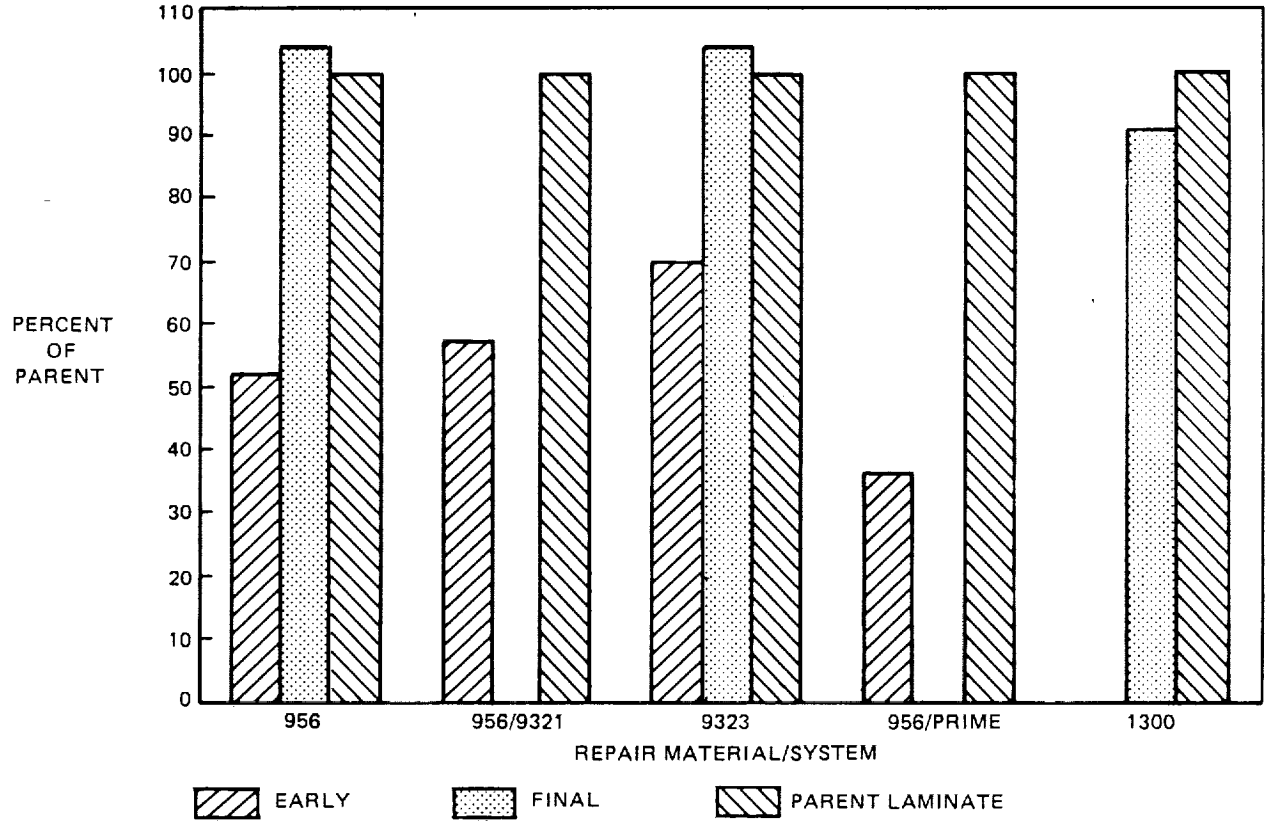
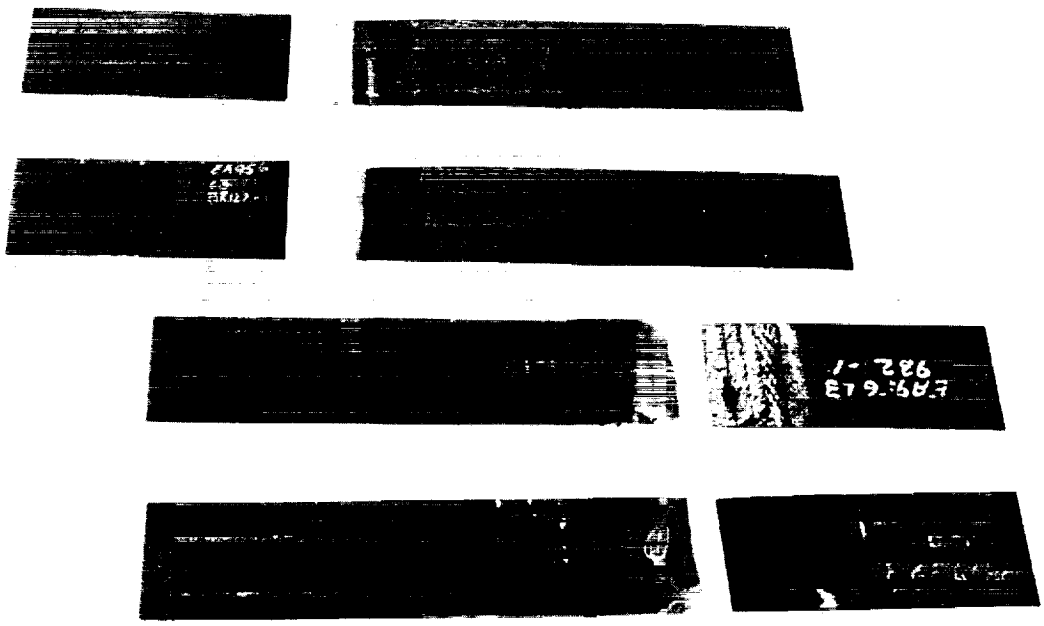


FIGURE 5. REPAIRED LAMINATE STRENGTH

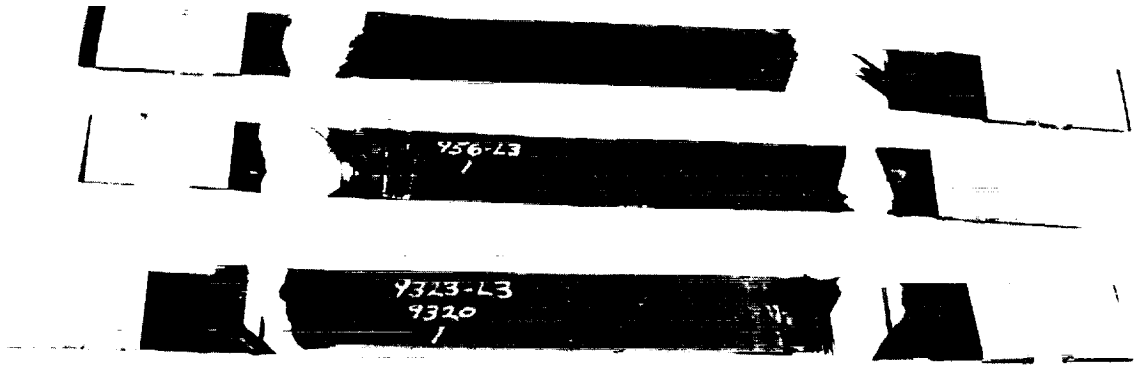
Figure 6 shows a view of an early repair test coupon that failed prematurely under static tension load. The failure occurred at the interface between the autoclave cured parent laminate and the repair laminate, as indicated in the figure by the very clean failure surface. The failure occurred at approximately 52 percent of the parent material strength. Figure 7 shows a final repair test coupon. In this case, the failure occurred outside of the repair zone in the parent laminate. This test verified that proper application of this repair technique will restore a damaged autoclave cure laminate to its original strength.

The rudder repair procedure is shown in schematic form in Figure 8. The front spar access plates were removed to locate the internal backup plates. The damaged skin and spar cap were sanded until the skin was tapered at a 50:1 length-to-thickness ratio. This taper ratio was determined during the repair development program. Figure 9 shows the prepared rudder after the damage was removed and the skin was tapered.



L5-04047

FIGURE 6 . EARLY REPAIR CONFIGURATION SHOWING COHESIVE FAILURE



L5-04044

FIGURE 7. FINAL REPAIR CONFIGURATION SHOWING PARENT LAMINATE FAILURE

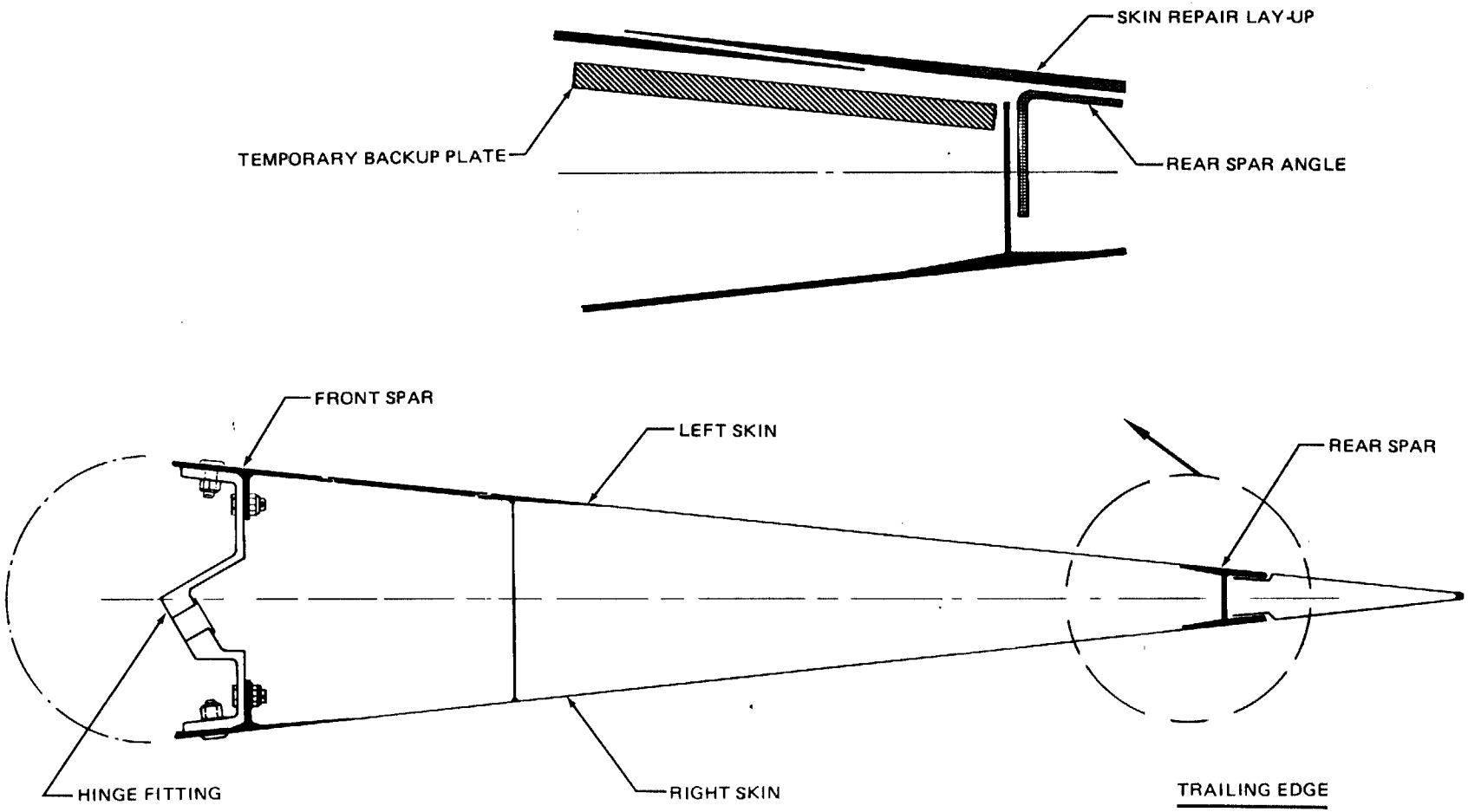
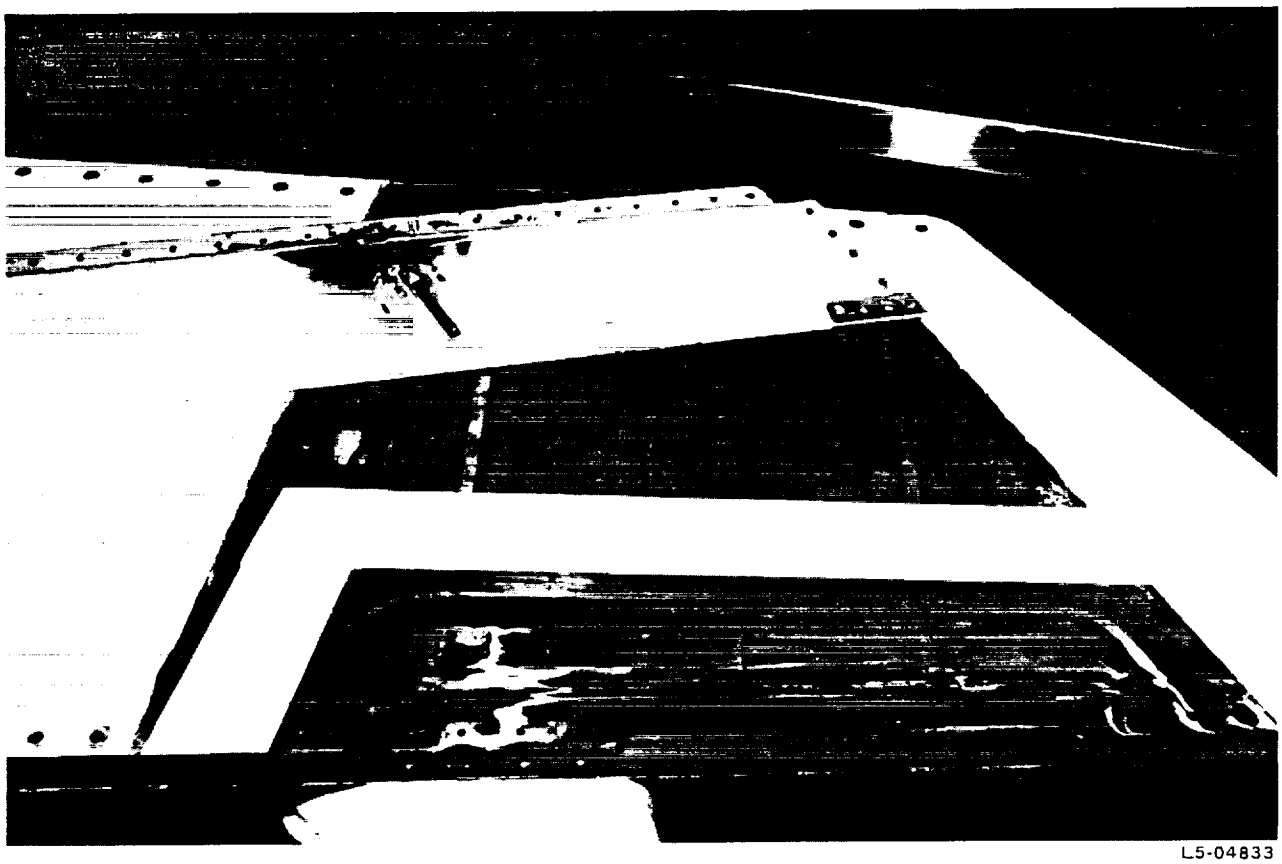


FIGURE 8. RUDDER REPAIR SCHEMATIC



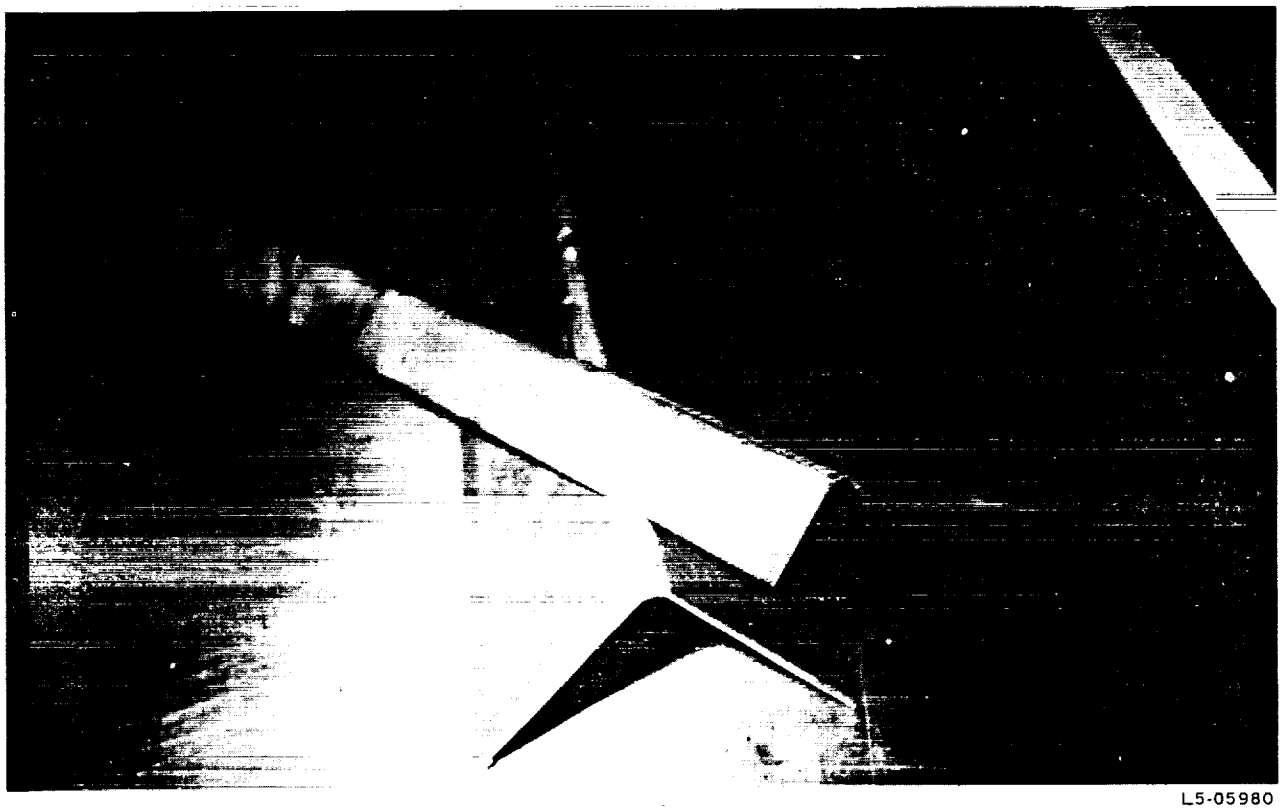
L5-04833

FIGURE 9. PREPARED RUDDER, READY FOR REPAIR

The spar cap was replaced by a precured bonded carbon angle. The angle was made on a simple "bent-to-fit" sheet metal tool. Dry carbon cloth was impregnated with resin and laid up on the tool. The angle was cured at 200°F under a heat lamp at vacuum pressure. The spar repair angle and tool are shown in Figure 10. The angle was then bonded to the spar web using Cleco's to provide bond line pressure. Figure 11 shows a view of the angle being positioned on the spar web.

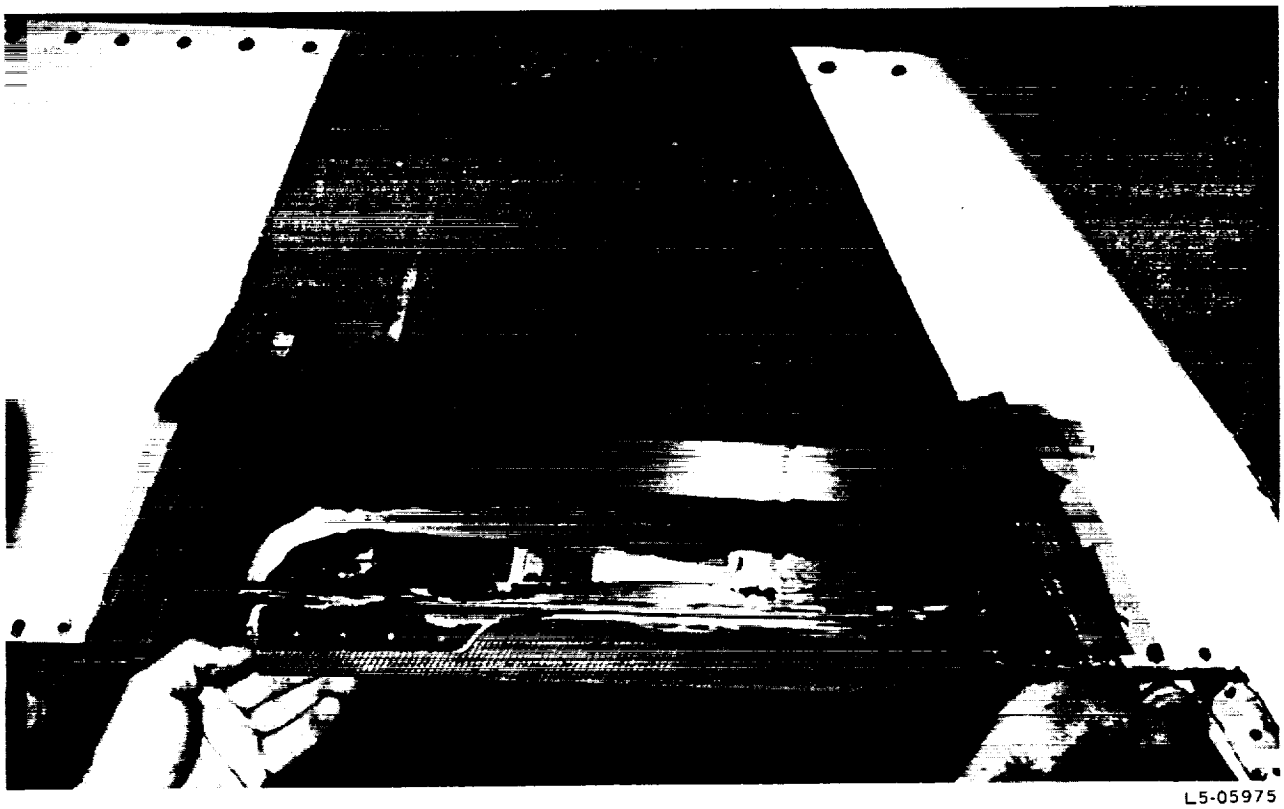
Templates defining the skin and spar cap repair plies were cut from Mylar and checked for fit, as shown in Figure 12. The skin was prepared for bonding and the bond surface verified by water break test. A single piece of carbon cloth was then impregnated with resin, as shown in Figure 13. The individual ply pieces were cut using the template and are shown being laid in place over the skin in Figures 14 and 15. The repair zone was vacuum bagged, as shown in Figure 16, and cured under a thermocouple-controlled heat blanket. The vacuum and heat were supplied by an ACR 9000 portable controller, manufactured by the Brisk Heat Company and shown in Figure 17.

After the cure operation was completed, the repair area was visually and ultrasonically inspected, the front spar access plates were replaced, and the fiberglass trailing edge was attached to the rudder. The completed repair is shown in Figure 18. The rudder will be painted and returned to flight service as soon as arrangements with the airline can be made.



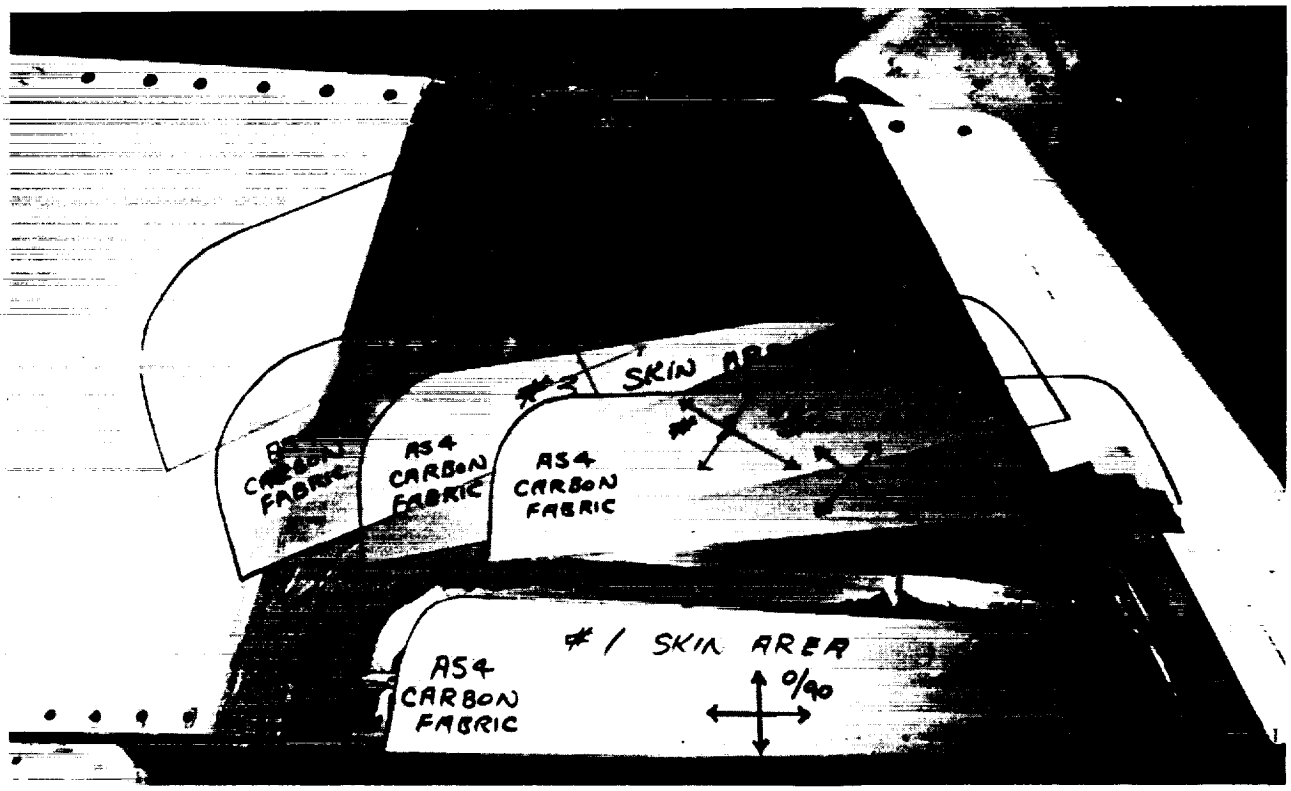
L5-05980

FIGURE 10. REPAIR SPAR AND TOOL



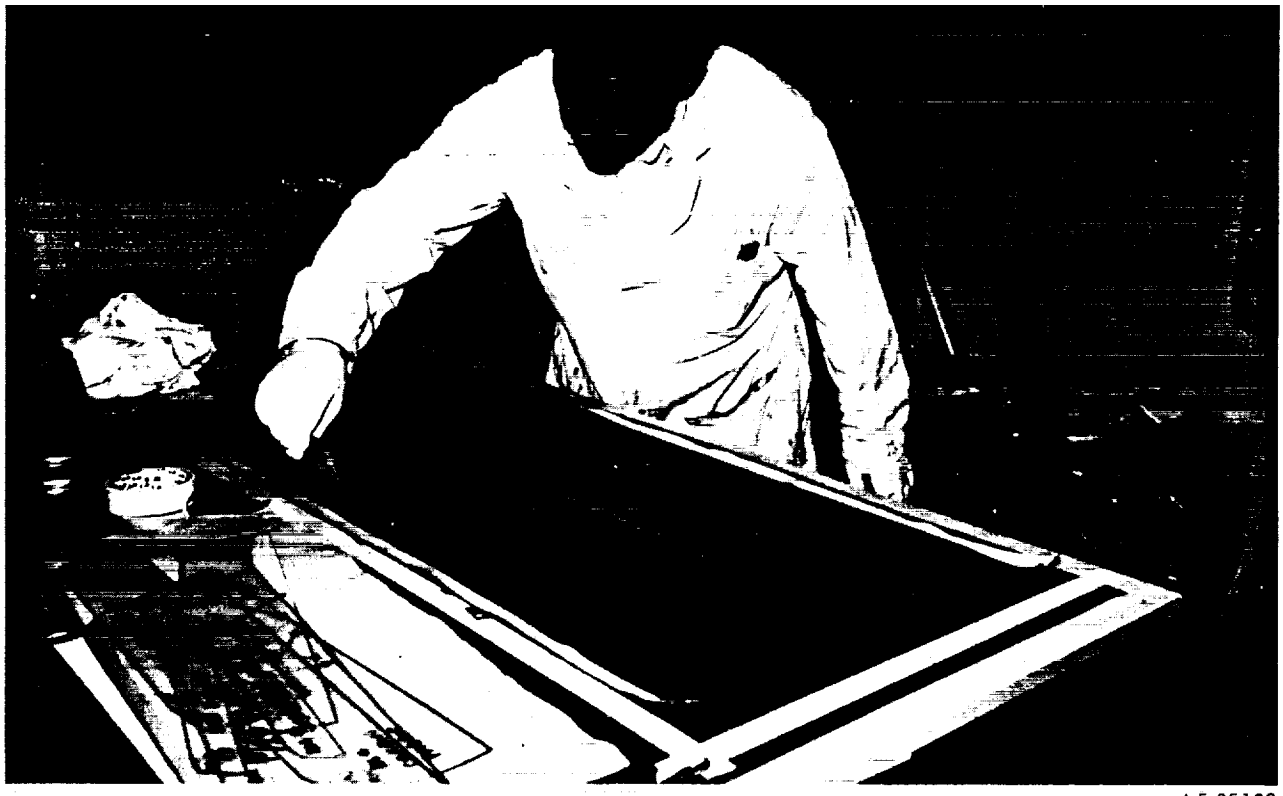
L5-05975

FIGURE 11. REAR SPAR REPAIR



L5-05974

FIGURE 12. PLY TEMPLATES



L5-06129

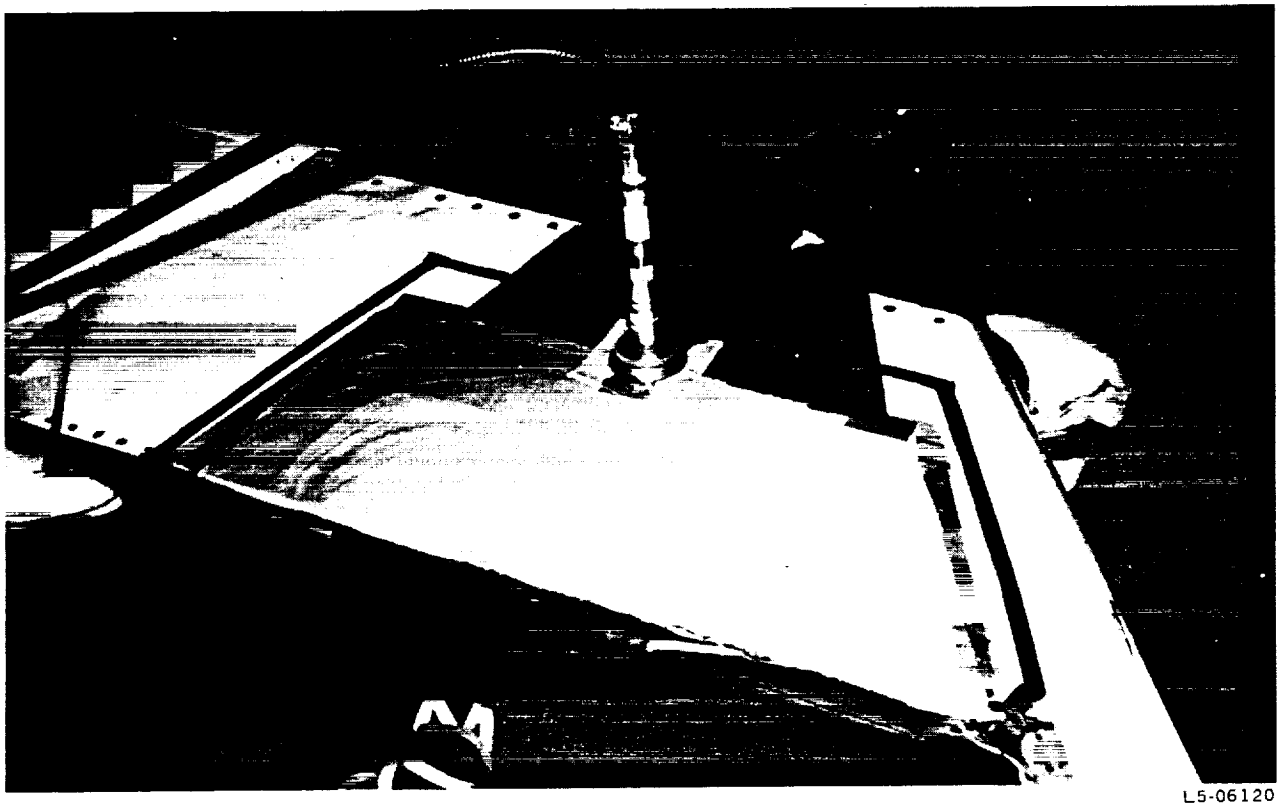
FIGURE 13. IMPREGNATING PROCESS

L5-06127

FIGURE 14. PLY LAY-UP

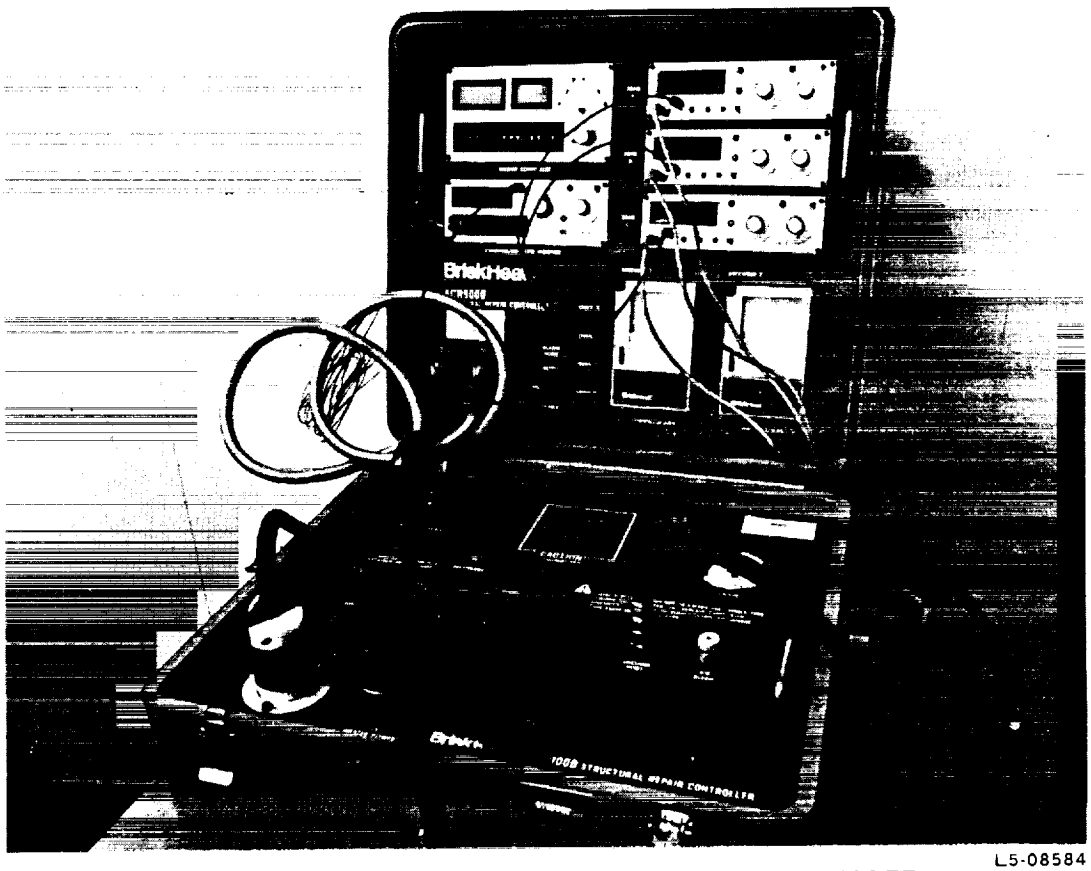
L5-06126

FIGURE 15. WET LAY-UP COMPLETION



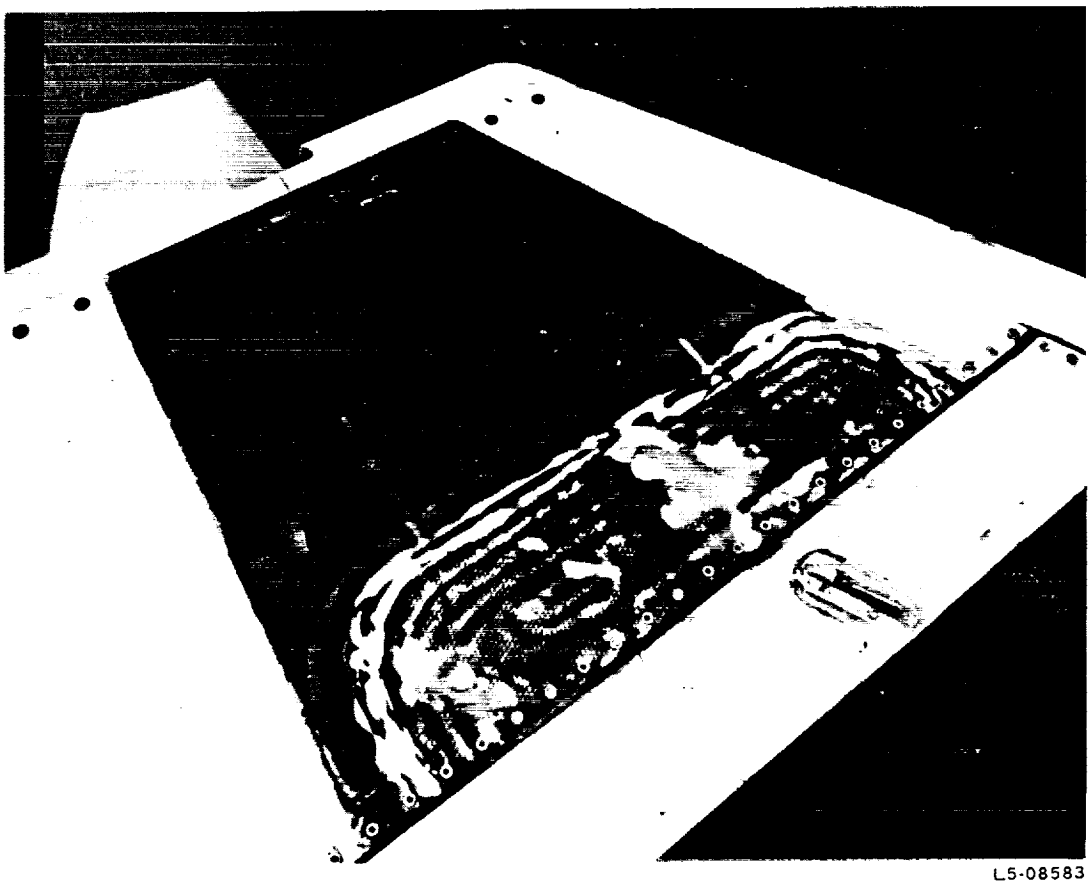
L5-06120

FIGURE 16. VACUUM BAG INSTALLATION



L5-08584

FIGURE 17. VACUUM AND HEAT SUPPLY AND CONTROLLER



L5-08583

FIGURE 18. COMPLETED RUDDER REPAIR

SECTION 4

ENVIRONMENTAL TESTS

Ground exposure specimens were deployed in exposure racks at San Francisco International Airport and at the NASA Langley Research Center in Hampton, Virginia in October and November 1974, respectively. Each rack contained 20 stressed specimens, which were preloaded in tension to approximately 36 percent of the ultimate tensile strength, and 20 unstressed specimens.

After outdoor exposure for 1, 3, 5, 7, and 10 years, four of the stressed and four of the unstressed specimens were removed from each rack and tested to failure in tension. Eight unstressed control specimens with no outdoor exposure were also tested before the exposure period began and eight unstressed specimens which were stored indoors for 10 years were tested at the end of the exposure period.

The test program has now been completed. In general, the residual tensile strengths of the outdoor specimens are within the scatter band for the strength of the baseline specimens. The test results indicate that the T300/5208 quasi-isotropic tensile specimens were unaffected by either the outdoor environment or the sustained tensile stress at the two exposure sites indicated. The test results are summarized in Tables 11 through 16 and in Figures 19 and 20.

TABLE 11
TENSILE TEST RESULTS FOR ENVIRONMENTAL EXPOSURE SPECIMENS
THORNEL 300/NARMCO 5208 LAMINATES (0/45/90/–45)s LAMINATE PATTERN

SPECIMEN TYPE	EXPOSURE CONDITION	SPECIMEN NUMBER	ULTIMATE LOAD		ULTIMATE TENSILE STRENGTH		AVERAGE ULTIMATE TENSILE STRENGTH	STANDARD DEVIATION	YOUNG'S MODULUS		MOISTURE CONTENT (PERCENT)	FAILURE LOCATION[1]
			N	lbf	MPa	psi	MPa (psi)	MPa (psi)	GPa	msi		
UNSTRESSED	BASELINE – NO EXPOSURE	81	6,761	1,520	500.16	72,539						G
		82	5,916	1,330	435.47	63,158						G
		83	6,539	1,470	473.44	68,664			56.8	8.24		T
		84	6,072	1,365	441.78	64,072	450.38	32.87	53.9	7.82		G
		85	5,605	1,260	408.83	59,294	(65,320)	(4,767)				G
		86	6,405	1,440	467.14	67,751						T
		87	6,428	1,445	469.33	68,068						G
		88	5,605	1,260	406.92	59,016						T
	10 YEARS' OFFICE STORAGE AT NASA-LRC HAMPTON, VIRGINIA	89	6,294	1,415	454.66	65,941			55.3	8.02		T
		90	6,094	1,370	441.23	63,993			57.3	8.31		G
		92	6,583	1,480	482.39	69,962					0.646	T
		93	6,895	1,550	500.38	72,571	465.52	27.28			0.658	T
		94	6,984	1,570	500.87	72,642	(67,515)	(3,957)				G
		95	6,005	1,350	435.81	63,207						T
		96	6,005	1,350	436.74	63,342						T
		99	6,628	1,490	472.07	68,465						G

(1) G – DENOTES FAILURE IN GAGE SECTION OF SPECIMEN. T – DENOTES FAILURE AT TANGENT POINT OF RADIUS AT END OF GAGE SECTION.

TABLE 12

TENSILE TEST RESULTS FOR ENVIRONMENTAL SPECIMENS
AFTER 1 YEAR OF EXPOSURE
THORNEL 300/NARMCO 5208 LAMINATES (0/45/90/-45) S LAMINATE PATTERN

SPECIMEN TYPE[1]	EXPOSURE SITE	SPECIMEN NUMBER	TENSILE TEST DATA[2]								MOISTURE CONTENT (PERCENT)	FAILURE LOCATION[3]
			ULTIMATE LOAD		ULTIMATE TENSILE STRENGTH		AVERAGE ULTIMATE TENSILE STRENGTH MPa (PSI)	STANDARD DEVIATION MPa (PSI)	YOUNG'S MODULUS			
			kg	LB	MPa	PSI			GPa	(MSI)		
STRESSED	SAN FRANCISCO, CALIFORNIA	1	517.10	1140	357.27	51,818	374.12 (54,261)	12.94 (1877)	52.26	7.58		G
		3	537.51	1185	371.38	53,864						G
		5	551.11	1215	380.78	55,227						T
		7	560.19	1235	387.04	56,136						T
	NASA-LRC HAMPTON, VIRGINIA	41	503.49	1110	347.87	50,455	428.57 (62,159)	54.54 (7911)	–	–		G
		43	657.71	1450	454.43	65,909						G
		45	675.85	1490	466.96	67,727						G
		47	644.10	1420	445.02	64,545						G
UNSTRESSED	SAN FRANCISCO, CALIFORNIA	2	523.90	1155	361.97	52,500	391.75 (56,818)	26.90 (3901)	52.26	7.58	0.61	T
		4	546.58	1205	377.65	54,773					0.77	T
		6	587.40	1295	405.85	58,864					1.02	T
		8	610.08	1345	421.52	61,136					1.46	T
	NASA-LRC HAMPTON, VIRGINIA	42	553.38	1220	382.35	55,455	413.68 (60,000)	29.95 (4344)	–	–	–0.49	T
		44	594.21	1310	410.55	59,545					–0.49	G
		46	657.71	1450	454.43	65,909					–0.49	T
		48	589.67	1300	407.42	59,091					–0.49	G

(1) STRESSED SPECIMENS WERE PRELOADED IN TENSION TO 36 PERCENT OF THE AVERAGE ULTIMATE TENSILE STRENGTH OF THE CONTROL SPECIMENS.
(2) ULTIMATE TENSILE STRENGTH (UTS) IS BASED ON A NOMINAL PLY THICKNESS OF 5.5 MILS.
(3) G – DENOTES FAILURE IN GAGE SECTION OF SPECIMEN. T – DENOTES FAILURE AT TANGENT POINT OF RADIUS AT END OF GAGE SECTION.

TABLE 13

TENSILE TEST RESULTS FOR ENVIRONMENTAL SPECIMENS
AFTER 3 YEARS OF EXPOSURE
THORNEL 300/NARMCO 5208 LAMINATES (0/45/90/-45) S LAMINATE PATTERN

SPECIMEN TYPE[1]	EXPOSURE SITE	SPECIMEN NUMBER	TENSILE TEST DATA[2]								MOISTURE CONTENT (PERCENT)	FAILURE LOCATION[3]
			ULTIMATE LOAD		ULTIMATE TENSILE STRENGTH		AVERAGE ULTIMATE TENSILE STRENGTH	STANDARD DEVIATION	YOUNG'S MODULUS			
			kg	LB	MPa	PSI	MPa (PSI)	MPa (PSI)	GPa	(MSI)		
STRESSED	SAN FRANCISCO, CALIFORNIA	15	(4)	–	–	–	421.43 (61,123)	62.90 (9123)			1.013	
		19	621.42	1370	431.77	62,623					1.010	T
		21	512.56	1130	354.00	51,343					1.018	T
		23	698.53	1540	78.51	69,403					1.020	G
	NAS-LRC HAMPTON, VIRGINIA	49	623.69	1375	463.63	67,244	455.40 (66,050)	22.48 (3261)	58.40	8.47	1.011	T
		51	635.03	1400	469.34	68,072					1.014	T
		53	628.23	1385	466.77	67,699					1.012	T
		55	569.26	1255	422.01	61,207					1.011	T
UNSTRESSED	SAN FRANCISCO, CALIFORNIA	10	566.99	1250	393.95	57,138	412.79 (59,876)	22.31 (3236)	53.64	7.78	1.012	T
		12	564.72	1245	393.33	57,047					1.009	T
		14	632.76	1395	435.62	63,182					1.009	T
		16	621.42	1370	428.41	62,136					1.010	T
	NASA-LRC HAMPTON, VIRGINIA	50	603.28	1330	455.27	66,031	428.99 (62,220)	44.80 (6498)	57.23	8.30	1.012	T
		52	526.17	1160	391.10	56,724					1.008	G
		54	526.17	1160	391.02	56,712					1.009	T
		56	646.37	1425	478.58	69,412					1.009	T

(1) STRESSED SPECIMENS WERE PRELOADED IN TENSION TO 36 PERCENT OF THE AVERAGE ULTIMATE TENSILE STRENGTH OF THE CONTROL SPECIMENS.
(2) ULTIMATE TENSILE STRENGTH (UTS) IS BASED ON A NOMINAL PLY THICKNESS OF 5.5 MILS.
(3) G – DENOTES FAILURE IN GAGE SECTION OF SPECIMEN. T – DENOTES FAILURE AT TANGENT POINT OF RADIUS AT END OF GAGE SECTION.
(4) SPECIMEN FAILED DURING REMOVAL FROM PRELOAD DEVICE.

TABLE 14

TENSILE TEST RESULTS FOR ENVIRONMENTAL SPECIMENS AFTER 5 YEARS OF EXPOSURE
THORNEL 300/NARMCO 5208 LAMINATES (0/45/90-45) S LAMINATE PATTERN

SPECIMEN TYPE[1]	EXPOSURE SITE	SPECIMEN NUMBER	TENSILE TEST DATA[2]								MOISTURE CONTENT (PERCENT)	FAILURE LOCATION[3]
			ULTIMATE LOAD		ULTIMATE TENSILE STRENGTH		AVERAGE ULTIMATE TENSILE STRENGTH	STANDARD DEVIATION	YOUNG'S MODULUS			
			kg	LB	MPa	PSI	MPa (PSI)	MPa (PSI)	GPa	MSI		
STRESSED	SAN FRANCISCO CALIFORNIA	9	646.37	1425	431.96	62,650			47.85	6.94	0.870	T
		11	542.04	1195	402.94	58,442	421.13	36.30			0.969	T
		13	596.47	1315	473.77	68,715	(61,079)	(5265)			0.758	T
		17	555.65	1225	375.83	54,510					1.018	T
	NASA-LRC HAMPTON, VIRGINIA	57	594.21	1310	440.31	63,862			51.92	7.53	1.223	T
		59	659.98	1455	502.65	72,904	450.84	31.63			1.467	T
		61	576.06	1270	416.88	60,464	(65,389)	(4588)			1.843	T
		63	605.55	1335	443.50	64,324					2.028	T
UNSTRESSED	SAN FRANCISCO CALIFORNIA	18	614.62	1355	431.13	62,530			52.33	7.59	0.561	T
		20	614.62	1355	455.70	66,094	449.99	21.21			0.613	T
		22	655.44	1445	477.55	69,763	(65,265)	(2671)			0.644	T
		24	601.01	1325	435.55	63,171					0.543	T
	NASA-LRC HAMPTON, VIRGINIA	58	601.01	1325	449.61	65,210			51.92	7.53	0.455	T
		60	621.42	1370	475.81	69,011	464.87	17.46			0.689	T
		62	612.35	1350	446.33	64,735	(67,424)	(2533)			0.774	T
		64	680.39	1500	487.74	70,741					0.649	T

(1) STRESSED SPECIMENS WERE PRELOADED IN TENSION TO 36 PERCENT OF THE AVERAGE ULTIMATE TENSILE STRENGTH OF THE CONTROL SPECIMENS.
(2) ULTIMATE TENSILE STRENGTH (UTS) IS BASED ON A NOMINAL PLY THICKNESS OF 5.5 MILS.
(3) G - DENOTES FAILURE IN GAGE SECTION OF SPECIMEN. T — DENOTES FAILURE AT TANGENT POINT OF RADIUS AT END OF GAGE SECTION.

TABLE 15

TENSILE TEST RESULTS FOR ENVIRONMENTAL SPECIMENS AFTER 7 YEARS OF EXPOSURE
THORNEL 300/NARMCO 5208 LAMINATES (0/45/90/−45)S LAMINATE PATTERN

SPECIMEN TYPE[1]	EXPOSURE SITE	SPECIMEN NUMBER	TENSILE TEST DATA[2]								MOISTURE CONTENT (PERCENT)	FAILURE LOCATION[3]
			ULTIMATE LOAD		ULTIMATE TENSILE STRENGTH		AVERAGE ULTIMATE TENSILE STRENGTH	STANDARD DEVIATION	YOUNG'S MODULUS			
			kg	LB	MPa	PSI	MPa (PSI)	MPa (PSI)	GPa	MSI		
STRESSED	SAN FRANCISCO CALIFORNIA	33	610.08	1,345	432.88	62,784	420.75 (61,024)	30.42 (4,412)	48.61	7.05	NOT DETERMINED	T
		35	621.42	1,370	445.07	64,552						T
		37	528.44	1,165	376.32	54,581						T
		39	632.76	1,395	428.71	62,179						T
	NASA-LRC HAMPTON, VIRGINIA	65	628.22	1,385	449.10	65,137	447.62 (64,922)	29.51 (4,280)	51.16	7.42		G
		67	628.22	1,385	451.23	65,445						T
		69	561.55	1,238	409.14	59,341						T
		71	680.39	1,500	481.03	69,767						G
UNSTRESSED	SAN FRANCISCO CALIFORNIA	34	678.12	1,495	471.79	68,427	449.75 (65,231)	38.38 (5,566)	51.71	7.50		T
		36	644.10	1,420	463.73	67,258						T
		38	662.24	1,460	471.05	68,320						T
		40	564.72	1,245	392.44	56,919						T
	NASA-LRC HAMPTON, VIRGINIA	66	648.64	1,430	467.18	67,759	452.44 (65,621)	10.93 (1,586)	47.30	6.86		G
		68	605.55	1,335	446.73	64,793						T
		70	596.47	1,315	442.10	64,121						T
		72	650.90	1,435	453.76	65,812						T

(1) STRESSED SPECIMENS WERE PRELOADED IN TENSION TO 36 PERCENT OF THE AVERAGE ULTIMATE TENSILE STRENGTH OF THE CONTROL SPECIMENS.
(2) ULTIMATE TENSILE STRENGTH (UTS) IS BASED ON A NOMINAL PLY THICKNESS OF 5.5 MILS.
(3) G — DENOTES FAILURE IN GAGE SECTION OF SPECIMEN. T — DENOTES FAILURE AT TANGENT POINT OF RADIUS AT END OF GAGE SECTION.

TABLE 16

TENSILE TEST RESULTS FOR ENVIRONMENTAL SPECIMENS AFTER 10 YEARS OF OUTDOOR EXPOSURE

THORNEL 300/NARMCO 5208 LAMINATES (0/45/90/–45)s LAMINATE PATTERN

SPECIMEN TYPE[1]	EXPOSURE SITE	SPECIMEN NUMBER	ULTIMATE LOAD		ULTIMATE TENSILE STRENGTH		AVERAGE ULTIMATE TENSILE STRENGTH MPa (psi)	STANDARD DEVIATION MPa (psi)	YOUNG'S MODULUS		MOISTURE CONTENT (PERCENT)	FAILURE LOCATION[2]
			N	lbf	MPa	psi			GPa	msi		
STRESSED	SAN FRANCISCO, CALIFORNIA	25	6,072	1,365	442.33	64,153			56.5	8.20	0.707	T
		27	5,071	1,140	387.32	56,174	424.15	31.90	49.6	7.19	0.825	G
		29	5,938	1,335	442.80	64,221	(61,516)	(4,626)			0.773	T
		31[3]	4,204	945	320.87	46,537					0.679	G
	NASA-LRC HAMPTON, VIRGINIA	73[4]	–	–	–	–	–	–	–	–	1.152	
		75	6,917	1,555	501.02	72,664	471.78	35.14	57.4	8.32	0.886	T
		77	6,027	1,355	432.79	62,769	(68,424)	(5,097)	55.0	7.97	1.036	G
		79	6,606	1,485	481.55	69,840					1.014	T
UNSTRESSED	SAN FRANCISCO, CALIFORNIA	26	5,872	1,320	432.36	62,706			54.7	7.93	0.652	T
		28	5,471	1,230	413.40	59,956	419.91	15.38	55.4	8.04	0.607	G
		30	5,671	1,275	432.65	62,749	(60,900)	(2,231)			0.606	G
		32	5,356	1,204	401.21	58,188					0.670	T
	NASA-LRC HAMPTON, VIRGINIA	74	6,139	1,380	442.38	64,160			53.8	7.81	0.865	T
		76	5,938	1,335	427.96	62,068	446.12	20.56	55.8	8.09	0.845	G
		78	6,539	1,470	475.57	68,973	(64,702)	(2,982)			0.761	T
		80	5,961	1,340	438.56	63,606					0.794	G

(1) STRESSED SPECIMENS WERE PRELOADED IN TENSION TO 36 PERCENT OF THE AVERAGE ULTIMATE TENSILE STRENGTH OF THE CONTROL SPECIMENS.
(2) G – DENOTES FAILURE IN GAGE SECTION OF SPECIMEN, T – DENOTES FAILURE AT TANGENT POINT OF RADIUS AT END OF GAGE SECTION.
(3) SPECIMEN 31 OVERSTRESSED BY 50 PERCENT DURING EXPOSURE. RESULTS NOT INCLUDED IN AVERAGE STRENGTH.
(4) SPECIMEN 73 BROKEN DURING REMOVAL FROM EXPOSURE FIXTURE.

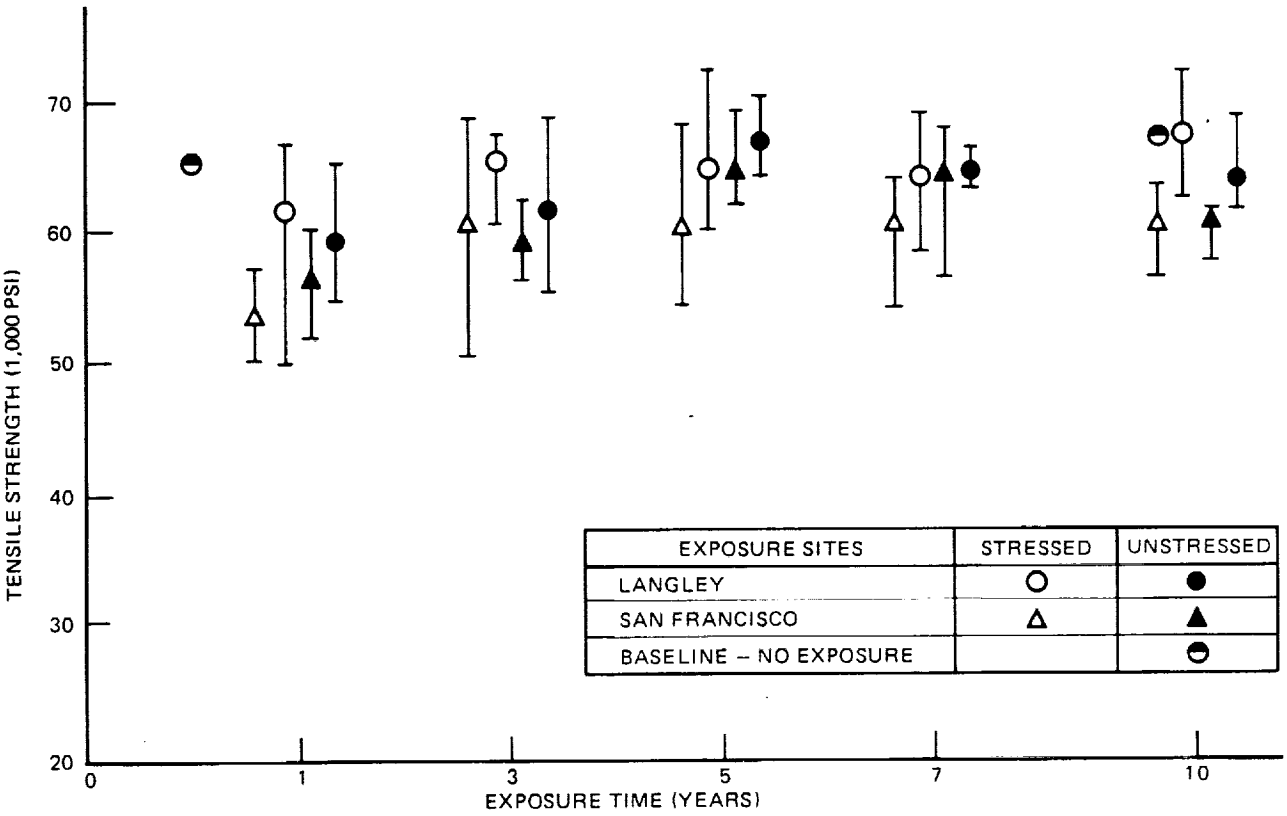


FIGURE 19. AVERAGE TENSILE STRENGTH VERSUS EXPOSURE TIME FOR ENVIRONMENTAL SPECIMENS

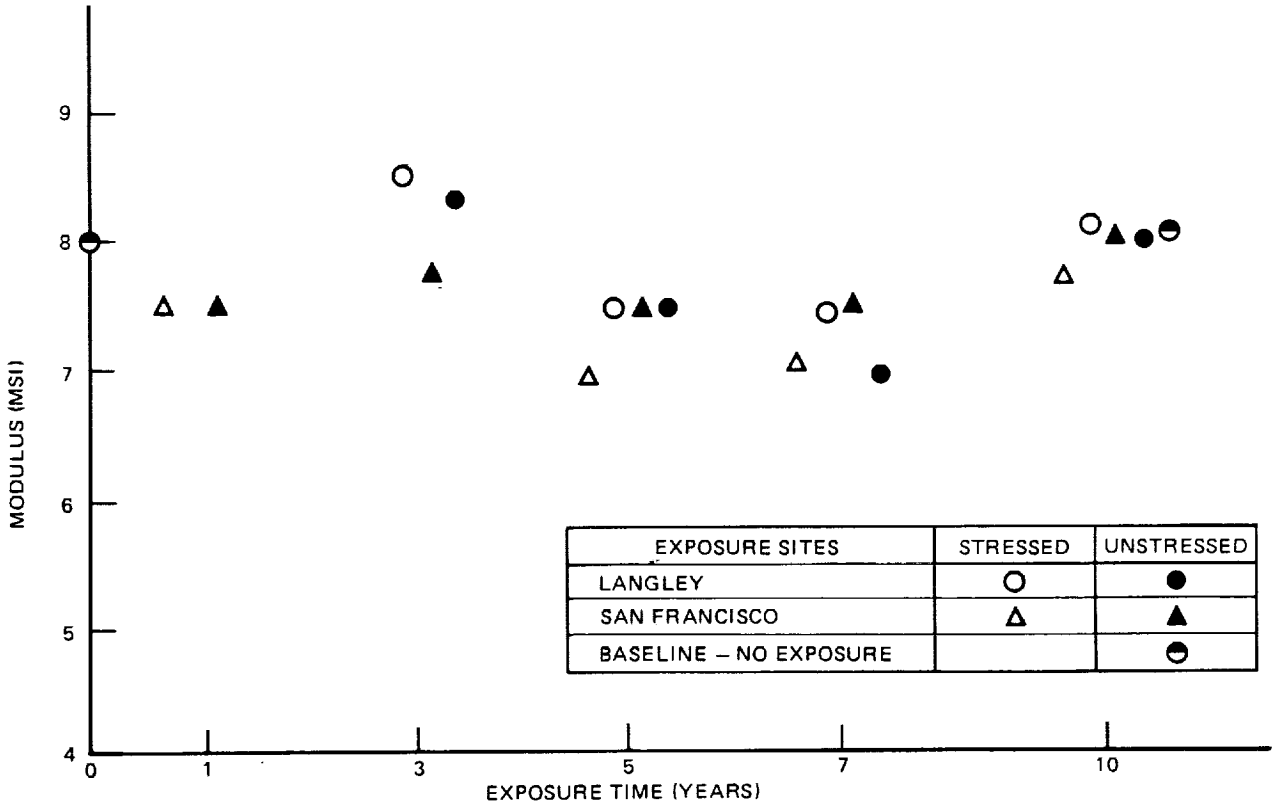


FIGURE 20. TENSILE MODULUS OF ELASTICITY VERSUS EXPOSURE TIME FOR ENVIRONMENTAL SPECIMENS

SECTION 5

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